PB-227 831

ANALYTICAL REFERENCE SERVICE TRAINING PROGRAM. WATER SURFACTANT NUMBER 2, MAY 1964

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

May 1964

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

PB 227 831

WATER SURFACTANT NO. 2

Report of a study conducted by the
ANALYTICAL REFERENCE SERVICE
TRAINING PROGRAM

Department of Health, Education, and Welfare
Public Health Service
Bureau of State Services
Division of Water Supply and Pollution Control

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio
1964

113

i,

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

CONTENTS

	PAGE
FOREWORD	iii
COMPLETED REPORTS	iv
PARTICIPANTS IN THIS STUDY	v
PURPOSE OF STUDY	1
DESIGN OF THE STUDY	1
TREATMENT OF DATA	4
DISCUSSION	4
SAMPLE A (Distilled Water)	4
SAMPLE B (Sewage)	13
SAMPLE C (Surface Water)	22
COMMENTS OF PARTICIPANTS	31
SUMMARY AND CONCLUSIONS	34
TABULATION OF RESULTS	35
ANALYTICAL PROCEDURES EVALUATED	89
GLOSSARY OF STATISTICAL TERMS	97
ANALYTICAL REFERENCE SERVICE MEMBERSHIP	100
ACKNOWLEDGEMENTS	105

FOREWORD

The Analytical Reference Service is conducted by the Training Program of the Robert A. Taft Sanitary Engineering Center for evaluation of laboratory methods in the environmental field. Cooperative studies by member organizations, through analysis of identical samples and critical review of methodology, provide the mechanism for:

> Evaluation of analytical procedures, including precision and accuracy, by comparison of procedures and results reported by participating laboratories.
>
> Exchange of information regarding method characteristics.
>
> Improvement or replacement of existing methods by development of more accurate procedures, and development of new methodology for determination of new pollutional components.

Samples are designed to contain measured amounts of selected constituents. Decisions as to qualitative makeup are made by the ARS staff, the membership, and consultants. Notice of each study is sent to the entire membership.

A portion of the study sample is then shipped to all who express a desire to participate, with accompanying data forms for reporting numerical values, a critique of the procedures used, and comments on modifications, sources of error, difficulties encountered, or other pertinent factors. The results and comments of each study are compiled and a report is prepared.

Initially directed toward examination of water, studies now include air, milk, and food. Some studies are periodically repeated for the advantage of new members, to evaluate new methods, or to re-evaluate existing methods.

The selection of studies is guided by the responses to questionnaries periodically circulated among the membership, which now includes 182 federal, state, and municipal agencies, industries, universities, consulting firms, and foreign agencies.

James P. Sheehy

James P. Sheehy
Director, Training Program

STUDIES ON WHICH REPORTS HAVE BEEN COMPLETED

Water-Minerals	Calcium, magnesium, hardness, sulfate, chloride, alkalinity, nitrite, nitrate, sodium, and potassium. Studies completed in 1956, 1958, and 1961.
Water-Metals	Lead, copper, cadmium, aluminum, chromium, iron, manganese, and zinc. Studies completed in 1957 and 1962.
Water-Fluoride	Fluoride in the presence and absence of interferences, with and without distillation using a specified procedure. Studies completed in 1958 and 1961.
Water-Radioactivity	Studies completed in 1959, 1961, and 1963. The first two studies were designed to determine gross beta activity, while the third study was concerned with gross beta and strontium-90 activity.
Water-Surfactant	Surfactant in various waters. Studies completed in 1959 and 1963.
Water Oxygen-Demand	Biochemical oxygen demand and chemical oxygen demand. Study completed in 1960.
Water Trace-Elements	Arsenic, boron, selenium, and beryllium. Study completed in 1962.
Air-Inorganics	Chloride, sulfate, fluoride, and nitrate in aqueous solution and on glass fiber hi-vol filter mats. Study completed in 1958.
Air-Lead	Filter paper tape impregnated with lead. Study completed in 1961.
Air Sulfur-Dioxide	Determination of sulfur dioxide in air using a specified method. Study completed in 1963.
Milk DDT-Residue	DDT in milk. Study completed in 1962.

PARTICIPANTS IN THIS STUDY

STATE AGENCIES

Alabama Water Improvement Commission
Arizona State Department of Health
Arkansas Water Pollution Control Commission
California Department of Water Resources, Sacramento
California Department of Water Resources, San Bernardino
California State Department of Public Health, Los Angeles
Colorado Department of Public Health, Denver
Connecticut State Department of Health
Delaware Water Pollution Commission
Florida State Board of Health (Bureau of Laboratories, Jacksonville)
Florida State Board of Health (Division of Sanitary Engineering, Jacksonville)
Idaho Department of Health
Illinois Department of Public Health (Chicago)
Illinois State Water Survey Division
Indiana State Board of Health
Kentucky State Department of Health
Louisiana State Board of Health
Maryland State Department of Health
Massachusetts Department of Public Health
Michigan Water Resources Commission
Minnesota State Department of Health
Montana State Board of Health
Nebraska State Department of Health
New Hampshire Water Pollution Commission
New Jersey State Department of Health
New Mexico State Department of Public Health
New York State Department of Health
New York State Conservation Department
North Carolina Department of Water Resources
Ohio State Department of Health
Oklahoma State Health Department
Oregon State Board of Health
Pennsylvania Department of Health
Rhode Island Department of Health
South Carolina Water Pollution Control Authority
Tennessee Stream Pollution Control Board

Texas State Department of Health
Vermont State Department of Water Resources
Virginia State Water Control Board
Wisconsin State Board of Health

MUNICIPAL AGENCIES

Chicago Department of Water and Sewers, South District Filtration Plant
City of Dayton Department of Water
City of Durham Department of Water Resources
City of Miami, Alexander Orr, Jr., Water Treatment Plant
City of New York Department of Health
Erie County Laboratory (Buffalo)
Flint Water Plant, Department of Public Works and Utilities
Los Angeles County Flood Control District
Los Angeles Department of Public Works (Hyperion Treatment Plant)
Los Angeles Department of Water and Power
Metropolitan Water District of Southern California
Omaha Metropolitan Utilities District
Philadelphia Suburban Water Company
Philadelphia Water Department (Torresdale Laboratory)
St. Louis County Water Company

FEDERAL AGENCIES

DHEW, PHS, Great Lakes - Illinois River Basins Project
DHEW, PHS, Water Quality Section, Division of Water Supply and Pollution Control, Cincinnati, Ohio
2793D U. S. Air Force Hospital, Regional Environmental Health Laboratory, McClelland AFB, California
2794th U.S. Air Force Dispensary - Class B, Kelly AFB, Texas
U. S. Army Environmental Hygiene Agency, Maryland
U. S. Department of the Interior, Bureau of Reclamation, Denver, Colorado
U. S. Department of the Interior, Geological Survey, Columbus, Ohio
U. S. Department of the Interior, Geological Survey, Denver, Colorado
U. S. Department of the Interior, Geological Survey, Sacramento, California

UNIVERSITIES

University of North Carolina, Chapel Hill
Washington State University, Division of Industrial Research

INDUSTRY

Atlantic Refining Company, Philadelphia, Pennsylvania
Ekroth Laboratories, Incorporated, Brooklyn, New York
Goodyear Atomic Corporation, Piketon, Ohio
Hall Laboratories Division, Calgon Corporation, Pittsburgh, Pennsylvania
Industrial Chemicals, Incorporated, South Bend, Indiana
Radiation Detection Company, Mountain View, California

FOREIGN

Caracas, Venezuela, Instituto Nacional de Obras Sanitarias
Hamilton, Ontario, Department of Municipal Laboratories
Kingston, Jamaica, West Indies, Scientific Research Council
Leatherhead, Surrey, England, Central Electricity Research Laboratories
London, England, The Permutit Company, Ltd.
Marlow, Buckinghamshire, England, The Water Research Association
Ottawa, Ontario, Canada, Department of National Health and Welfare
Taiwan Institute of Environmental Sanitation, PHA, Taiwan
    Water Laboratory, Taipei
    Water Laboratory, Taichung
Vancouver, B.C., Canada, Department of National Health and Welfare

PURPOSE OF THE STUDY

The widespread use of detergents that exhibit little or no degradation in surface waters has produced many problems in water supply and pollution control. Prerequisite to an evaluation of these problems and the development of remedial measures is an efficient, reliable analytical procedure for identifying synthetic detergents and measuring the concentrations present.

This study was undertaken to evaluate the precision and accuracy of the three most widely used procedures for detergent analysis and the degree of reagent cleanup required to remove interferences. The three methods are based on the reaction of alkyl benzene sulfonate with methylene blue dye, which forms a chloroform-soluble blue complex which is measured spectrophotometrically. The methods differ in the degree of reagent cleanup provided.

The British Method is the most sophisticated. It involves preliminary removal of impurities by chloroform extraction of the reagents, using redistilled chloroform. The blue complex is formed at a high pH to assure complete reaction of the surfactant. It is extracted with chloroform and put through a second extraction at acid pH to remove inorganic interferences.

The Standard Method is less elaborate. Both the prewash of the reagents and redistillation of the chloroform are eliminated. The complex is formed at a slightly acidic pH and is put through a final acid wash similar to the British Method.

In the SEC (Sanitary Engineering Center) Method, the complex is formed at a low pH, is extracted with chloroform, and read spectrophotometrically. Cleanup steps for eliminating interferences are not provided. The three methods are reproduced in this report exactly as they appear in referenced literature (See pages 89 - 96).

DESIGN OF THE STUDY

The study consisted of three samples, designated A, B, and C (with Sample C in two parts), each to be analyzed in triplicate. Since evaluation of the three methods could impose too great a work load on the laboratories, the Standard and SEC Methods were assigned to one third of the participants, the British and SEC Methods to one third,

and the British and Standard Methods to the remaining third. By this arrangement, each method was evaluated by two thirds of the participants.

A study kit was supplied to each participant. It contained samples A and B in disposable polyethylene containers, a concentrated ABS solution in a sterile glass vial, a supply of standard ABS powder, and methylene blue powder. Included in the kit were procedural outlines for the assigned methods, a set of instructions, and data report forms. The ABS powder was a certified standard supplied by the Soap and Detergent Association to assure the use by all participants of an identical standard and to avoid introduction of any bias. The methylene blue powder was supplied to further reduce reagent variables. Descriptions of the three samples follow:

Sample A contained 0.40 mg of alkyl benzene sulfonate (ABS) per liter in distilled, de-ionized water.

Sample A, designed as a control, contained a low ABS concentration comparable to that found in mildly contaminated surface waters. If good precision and accuracy could be obtained in this sample, it was assumed that the same techniques would produce comparable accuracy and precision for the higher concentration in B sample. Any difference could be attributed to the presence of interferences. In application of technique the only difference would be a dilution factor.

Sample B consisted of filtered, domestic sewage containing 8.18 mg/l ABS.

Sewage for sample B was obtained from a small primary treatment plant receiving only domestic sewage. The analysis of this sample, prior to preparation for shipment, is listed on the following page:

	mg/l
ABS	7.45
Organic nitrogen	6.1
Nitrate nitrogen	0.062
Nitrite nitrogen	0.001
Ammonia nitrogen	17.0
Chloride	80
Hardness	326
BOD	64
COD	152
Suspended solids	28
Volatile suspended solids	28
pH	7.4
Turbidity	82

The pH of samples A and B was lowered to 1.0, prior to shipment, to inhibit biological activity. Participants were instructed to adjust the pH of these samples to 6.5 - 7.5 with 50% NaOH solution prior to analysis. If the determinations were not completed within one day following neutralization, the samples were to be placed under refrigeration.

Sample C was a surface-water sample to be collected by the participants and analyzed for the concentration of ABS present at the time of collection. A sterile concentrated solution of ABS was supplied to each participant for addition to the collected sample, to introduce a concentration of 2.60 mg/l ABS above the initial concentration.

This portion of the study provides a wider variety of subtrates and defines the precision and accuracy obtainable from many surface waters. The majority of participants gave detailed data defining the chemical quality of their individual samples. These data and correlations are discussed later in this report

TREATMENT OF DATA

The mean of the results reported by each participant was plotted on probability paper to determine the distribution. Values showing a gross deviation from the normal distribution line were rejected as nonrepresentative because of errors in calculation, dilution, or other indeterminate factors. The rejected values are circled on the probability plot. These rejected values were not included in the development of statistical parameters, nor are they used elsewhere in this report. According to the probability plots, a slightly non-normal distribution of results was produced by all three methods for Sample B, and by the SEC and Standard Methods for Sample C. This non-normal distribution prevents use of the standard deviation for reliable statistical prediction, but it is of value for general indication of the variation that may be expected. Statistical values obtained under these conditions should be regarded as provisional with the standard deviations more likely to be too high than too low. [1]

Calculation of the standard deviations was based on the difference between the average result submitted by each participant and the overall mean value reported for each method. Since the instructions included the request that results be reported to the nearest hundredth mg/l, the values reported to three decimal places were rounded off for uniformity, according to the rule in Standard Methods. [1] Average reported values are shown in the bar charts, and the different analytical methods employed are identified. Statistical terms, as used in this report, are defined in the Glossary.

DISCUSSION

SAMPLE A (Dosed Distilled Water)

Sample A design provided for evaluation of the precision and accuracy of the three surfactant methods on waters containing no interfering substances. Sample A was prepared by dosing distilled, deionized water to contain 0.45 mg/l ABS, by lowering the pH to 1.0 with sulfuric acid, and

[1] Standard Methods for the Examination of Water and Wastewater, 11th Edition, 1960. American Public Health Association, American Water Works Association, Water Pollution Control Federation.

packaging in disposable polyethylene containers. The containers were held in the Analytical Reference Service laboratory for one month before shipping to participants to assure stability of the ABS. A loss of 0.05 mg/l ABS occurred during the first two weeks of storage; none in the second two weeks. That no additional loss occurred during the two months the sample was in the participant laboratories was determined by the 224 analyses performed by three ARS chemists throughout this period. Based on these analyses, the actual concentration present at time of participant analysis was established at 0.40 mg/l.

The 0.05 mg/l ABS loss probably was due to adsorption on the walls of the mixing tank and sample containers (both polyethylene). The ARS laboratory was unable to confirm adsorption as the source of the loss, as the 0.05 mg/l concentration was too small to recover by successive extractions of containers.

The summary of statistical data for Sample A gives the values obtained by analysis of the mean results reported in Table 2, page 36.

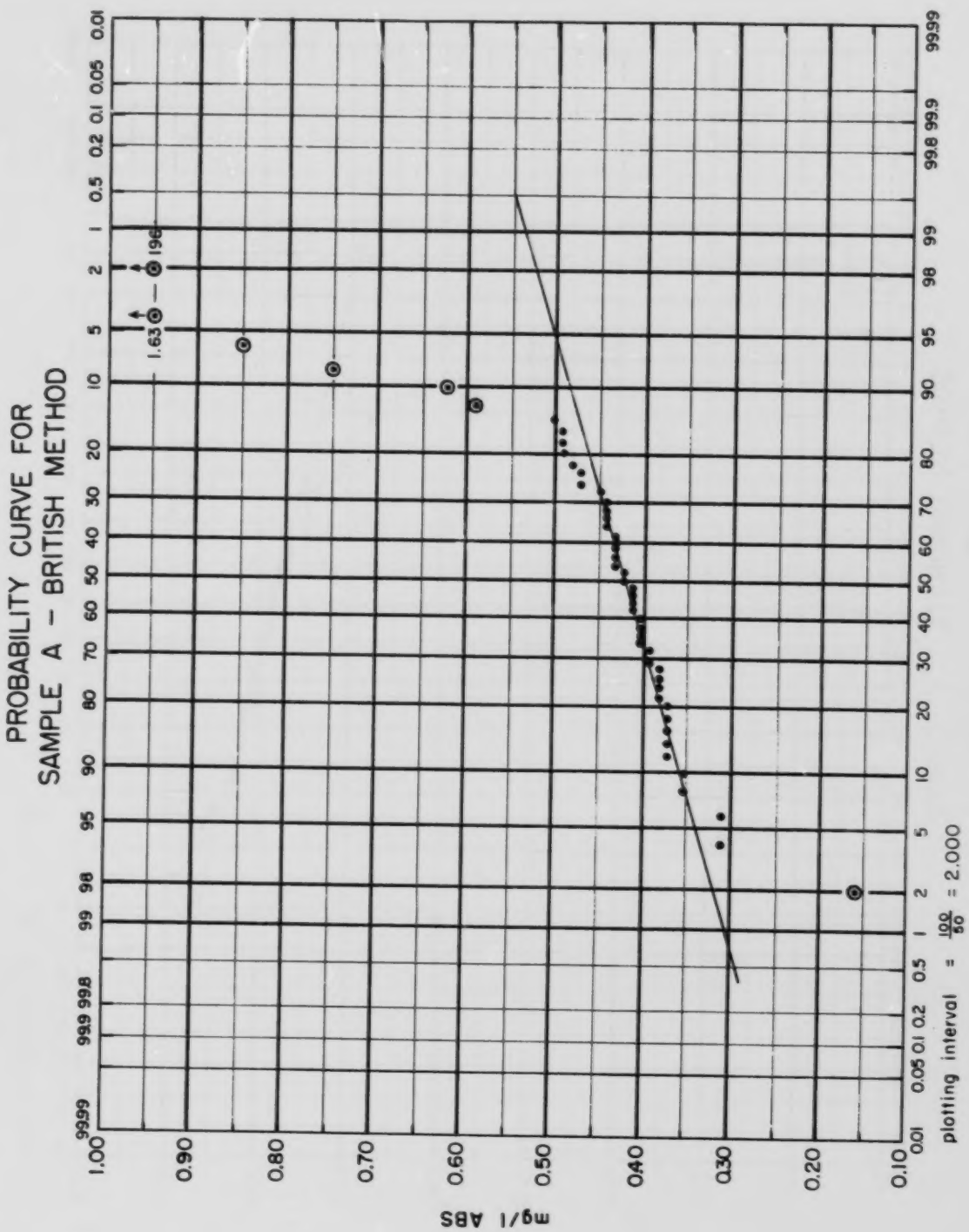
SUMMARY OF STATISTICAL DATA
Established ABS Concentration - 0.40 mg/l

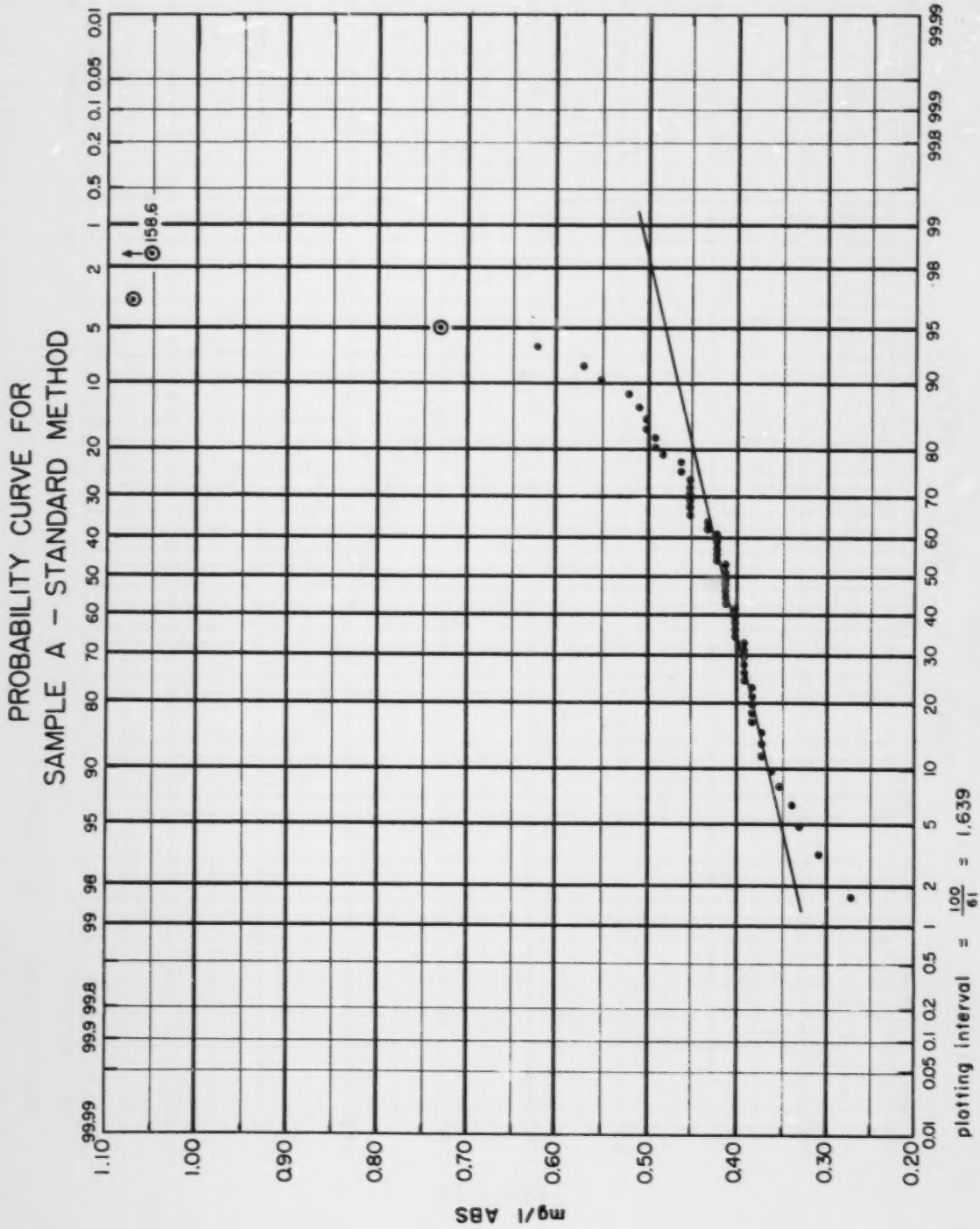
	British Method	Standard Method	SEC Method
Number of participants per method	42	57	56
Number of results	42	57	56
Mean	0.41	0.42	0.42
Median	0.41	0.41	0.42
Low and high results	0.31 - 0.50	0.27 - 0.62	0.28 - 0.58
Range	0.19	0.35	0.30
50% range	0.40 ± 0.03	0.40 ± 0.03	0.40 ± 0.04
Average deviation from established concentration	0.04	0.05	0.05
Standard deviation	0.046	0.062	0.062
95% confidence limits	0.41 ± 0.01	0.42 ± 0.02	0.42 ± 0.02
Coefficient of variation	11.2%	14.8%	14.8%

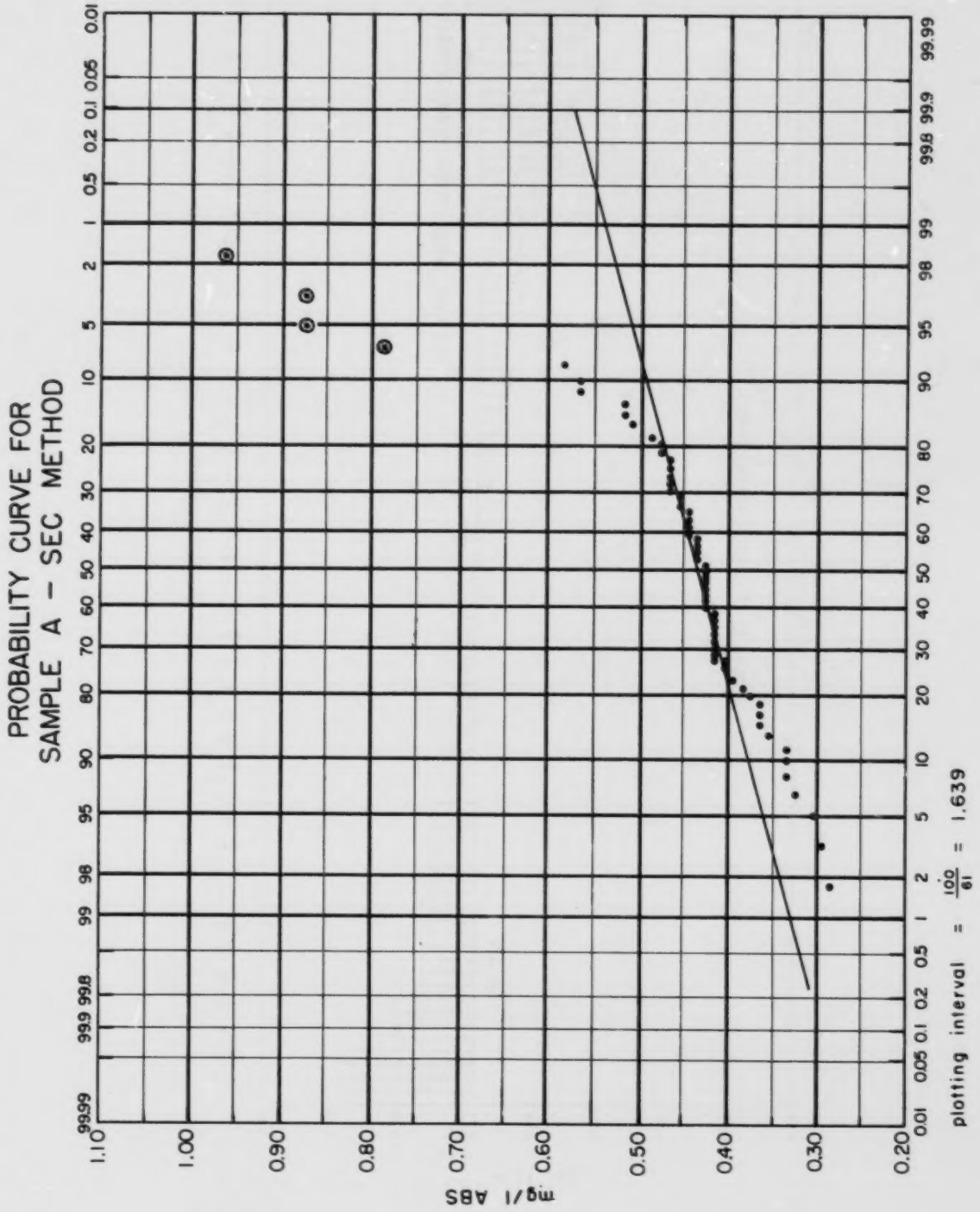
The British Method produced the best precision as indicated by the smaller standard deviation and the spread between low and high results. The British and Standard Methods produced slightly better accuracy than did the SEC Method with an average deviation of 0.04 mg/l from the established concentration as compared to 0.05 mg/l for the SEC Method. That 50% of all results were within $\pm$ 0.04 mg/l of the established concentration, regardless of method used, permits the conclusion that each of the three methods is satisfactory for the determination of ABS in waters containing no interferences.

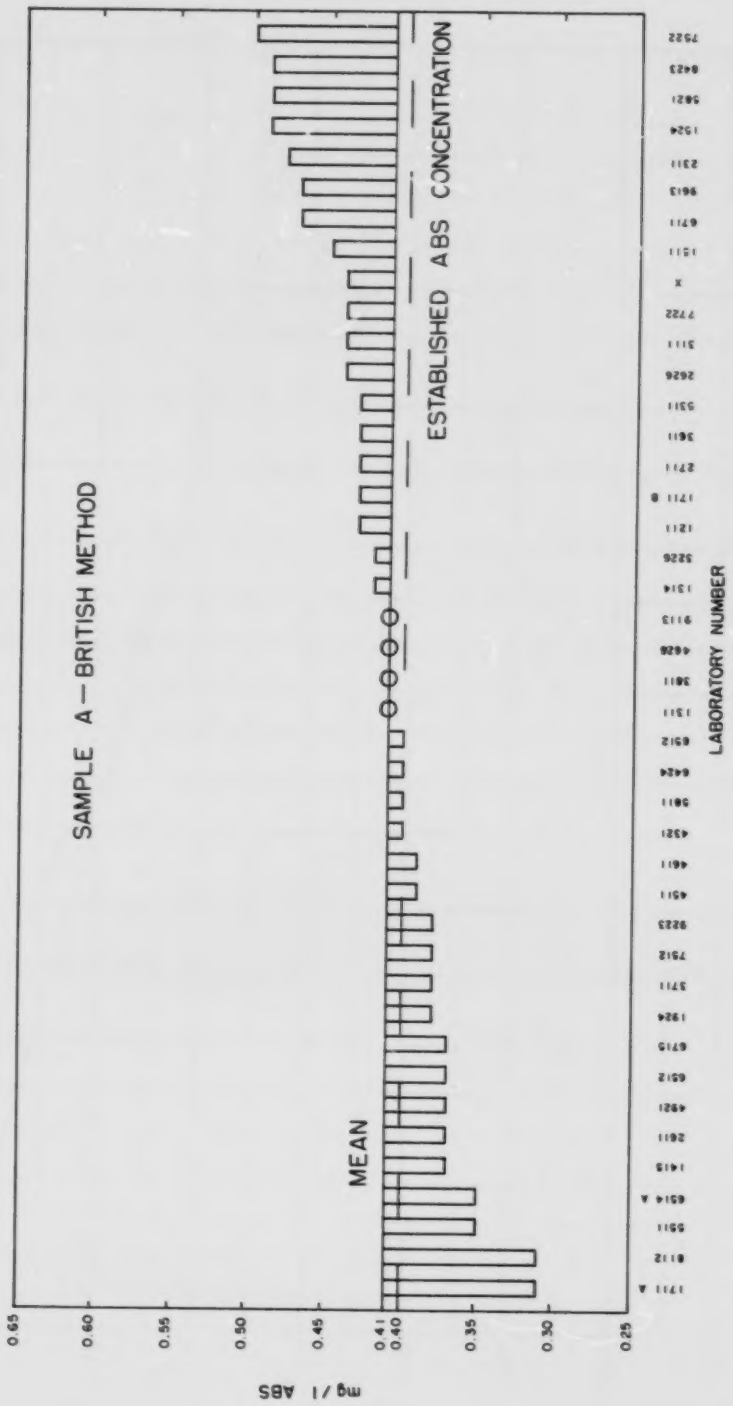
Probability curves were plotted for each of the methods evaluated (See pages 7, 8, 9). The mean reported values which fell significantly above or below the normal distribution were rejected as outliers. Seven values, circled on the probability curve, were rejected for the British Method, 3 for the Standard Method, and 4 for the SEC Method; from a total of 155 average values (from triplicate analyses), 14 were rejected as too erratic for inclusion in the statistical population.

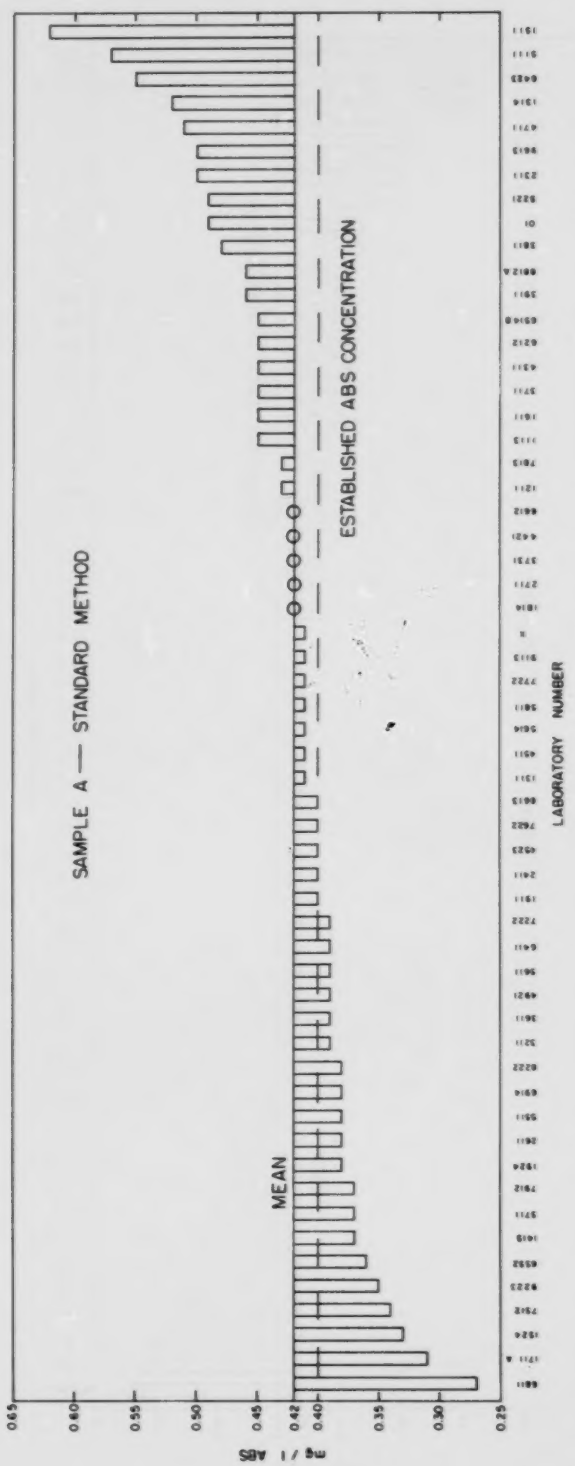
The bar graphs on pages 10, 11, and 12 visually depict the distribution of means reported by participants.

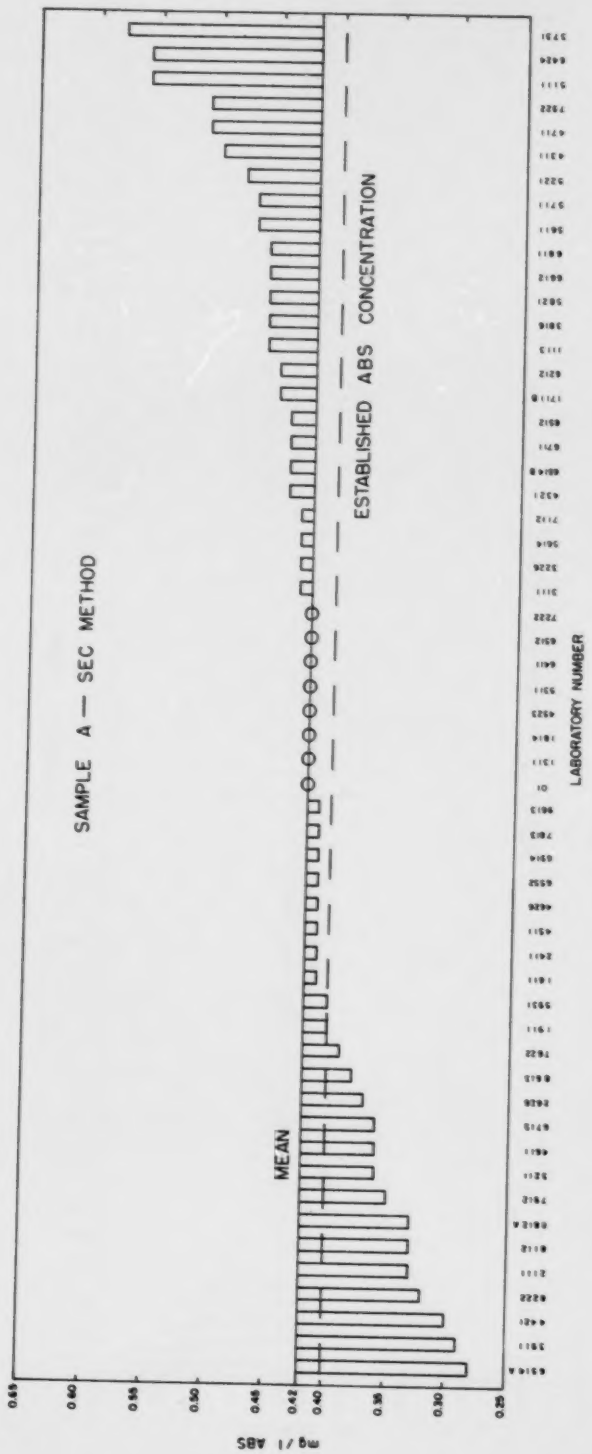

PROBABILITY CURVE FOR
SAMPLE A – BRITISH METHOD
mg/l ABS
1.63
1.96
plotting interval = 100/50 = 2.000


PROBABILITY CURVE FOR
SAMPLE A – STANDARD METHOD
mg/l ABS
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
158.6
plotting interval = 100/61 = 1.639


PROBABILITY CURVE FOR
SAMPLE A – SEC METHOD
mg/l ABS
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
99.99
99.9
99.8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01
plotting interval = 100/61 = 1.639


SAMPLE A — BRITISH METHOD
ESTABLISHED ABS CONCENTRATION
MEAN
mg / l ABS
0.65
0.60
0.55
0.50
0.45
0.41
0.40
0.35
0.30
0.25
LABORATORY NUMBER


SAMPLE A — STANDARD METHOD
ESTABLISHED ABS CONCENTRATION
MEAN
mg / l ABS
0.65
0.60
0.55
0.50
0.45
0.42
0.40
0.35
0.30
0.25
LABORATORY NUMBER


SAMPLE A — SEC METHOD
ESTABLISHED ABS CONCENTRATION
MEAN
LABORATORY NUMBER
mg / l ABS
0.65
0.60
0.55
0.50
0.45
0.42
0.40
0.35
0.30
0.25

SAMPLE B (Sewage)

Since analysis of sewage for ABS is generally considered to yield poor accuracy, Sample B design provided a means of evaluating the performance of the three methods for this media.

The sample was prepared by filtering primary sewage treatment-plant effluent to insure homogenity. Chemical analyses (see p. 3) showed an apparent ABS content of 7.45 mg/l for the filtered sewage, based on determinations by four chemists using four different methods with five replicates for each. The sample was dosed with 1.0 mg/l additional ABS to bring the concentration to the desired level. The theoretical concentration then became 8.45 mg/l. The sample was mixed in a large polyethylene tank with magnetic stirrers, the pH lowered to 1.0, and it was then packaged in disposable polyethylene containers. As with Sample A, Sample B containers were held in the ARS laboratory for one month before shipment to assure stability. Following neutralization (adjustment of pH to 6.5 - 7.5 with NaOH) participants were instructed to refrigerate the sample if not immediately analyzed.

Immediate analysis of the sample by the three prescribed methods produced an average ABS value of 8.48 mg/l, although agreement among methods was not as good as among replicates. Analyses were continued throughout the entire study period. A pronounced downward trend was evident for the first 2 weeks, after which the rate of loss decreased until, at the end of the 1-month holding period, there was no further loss of ABS.

The value for the concentration of ABS present in the sample at the time of analysis by participants was defined as 8.18 mg/l. While a total of 264 analyses were made of Sample B by the ARS staff over the 3-month study period, with each analyst using one of the specified methods, only the results obtained after stabilization of the concentration were used to establish the concentration of ABS present in the sample. The mean value of results obtained by the ARS laboratory from the British Method, after the 1-month stabilization period, was the 8.18 mg/l defined as the established concentration. The British Method was selected as the referee method, as it provided better elimination of interfering substances and produced results closer to the theoretical ABS values. A standard deviation of 0.462 mg/l was obtained from these results. During the entire ARS study the values showed erratic fluctuations, with the mean values for three methods seldom in close agreement, but with generally good agreement among replicates.

Several approaches were tried in an effort to pinpoint the cause of the ABS loss. Mycological examinations indicated no fungi present capable of degrading ABS. Bacteriological examinations indicated sterile conditions due to the 1.0 pH. It was assumed that part of the loss might be due to adsorption of ABS on the walls of the polyethylene containers. This assumption was confirmed during a brief adsorption study when approximately 0.3 mg of ABS was recovered from the walls of a 1-quart container used for storage of the sample for one month. The total loss in Sample B (0.27 mg/l) could have been due to many causes. The initial values may have been high due to positive interference from compounds which, in time, deteriorated to the point where they ceased to react. Conversely, organic materials in the sewage may have been converted to a form which would compete with the methylene blue in the reaction.

The summary of statistical data for Sample B gives the values obtained by analysis of the mean results reported in Table 3, page 52.

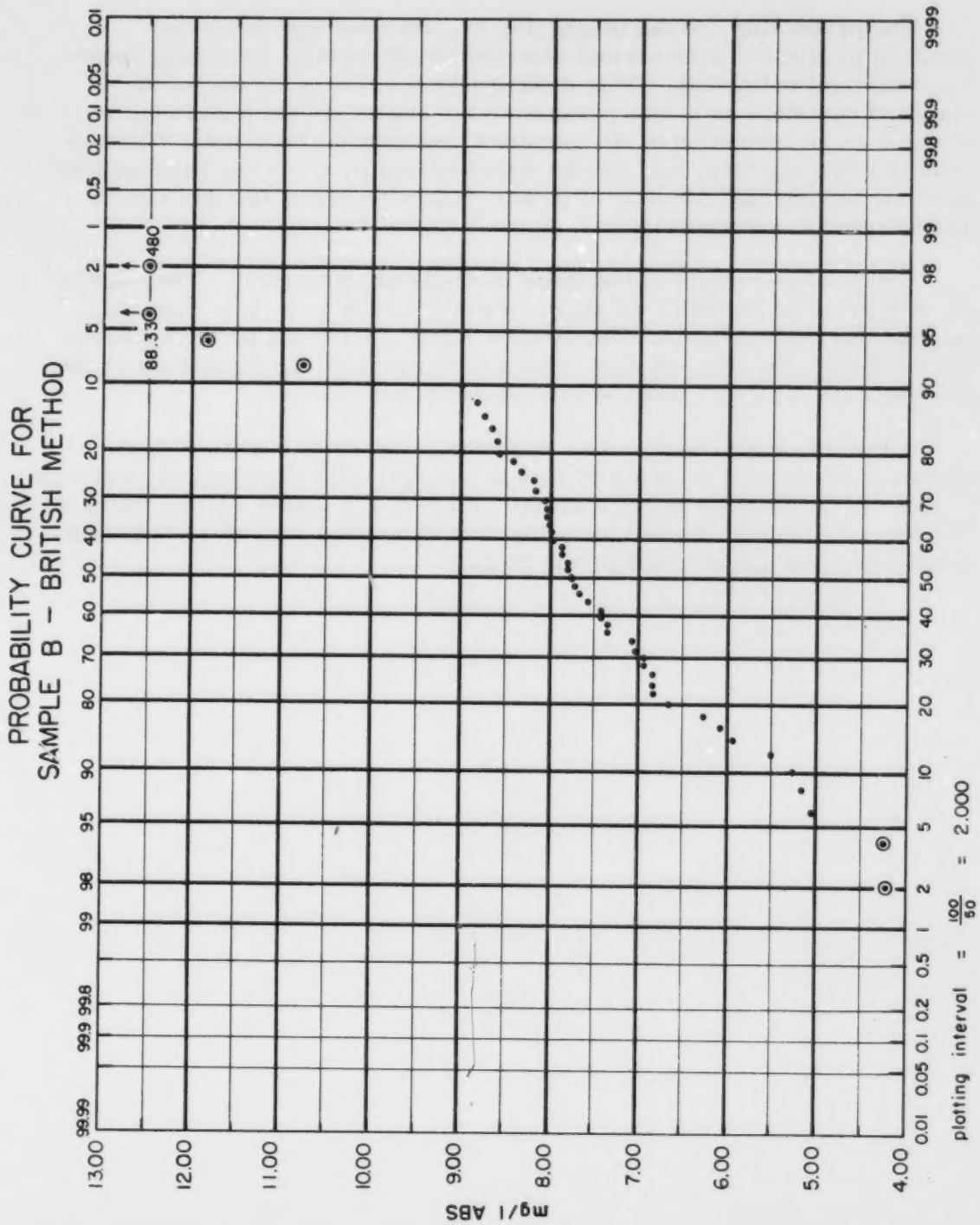
SUMMARY OF STATISTICAL DATA
Established ABS Concentration - 8.18 mg/l

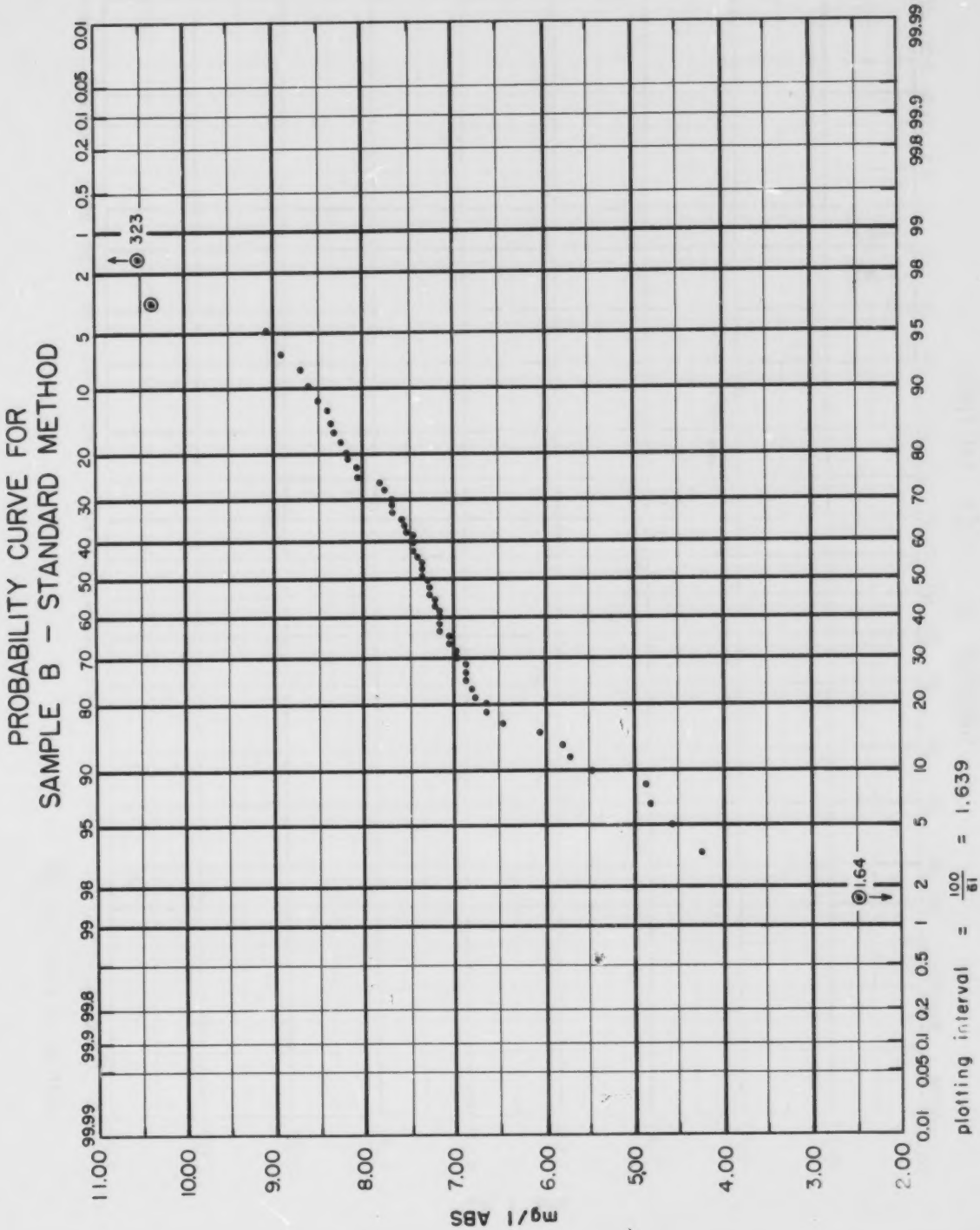
	British Method	Standard Method	SEC Method
Number of participants per method	43	57	56
Number of results	43	57	56
Mean	7.42	7.21	6.77
Median	7.70	7.30	6.90
Low and high results	5.03 - 9.00	4.25 - 9.07	4.33 - 8.69
Range	3.97	4.82	4.36
50% range	8.18 ± 0.62	8.18 ± 0.89	8.18 ± 1.28
Average deviation from established concentration	0.93	1.09	1.46
Standard deviation	1.010	1.039	1.062
95% confidence limits	7.42 ± 0.31	7.21 ± 0.28	6.77 ± 0.28
Coefficient of variation	13.6%	14.4%	15.7%

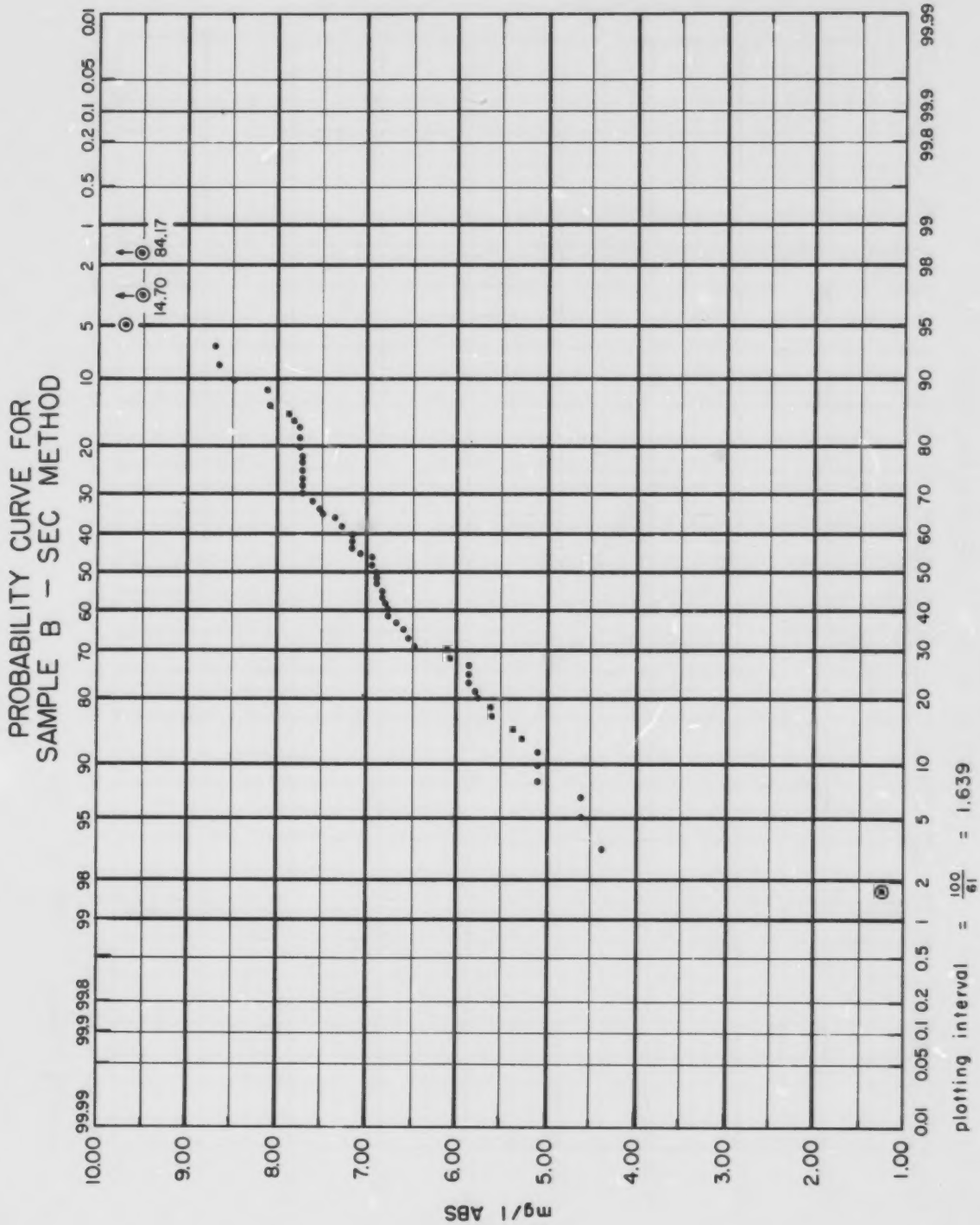
The probability curves (pages 16, 17, 18) show that the three methods produced a non-normal distribution of results, indicating doubtful statistical reliability. This distribution precludes the use of the standard deviation as a safe parameter for statistical prediction but is of value as an indication of the variation that may be expected. Thirteen results were rejected, six for the British Method, three for the Standard, and four for the SEC Method. The bar graphs on pages 19, 20, and 21, again, provide a visual aid.

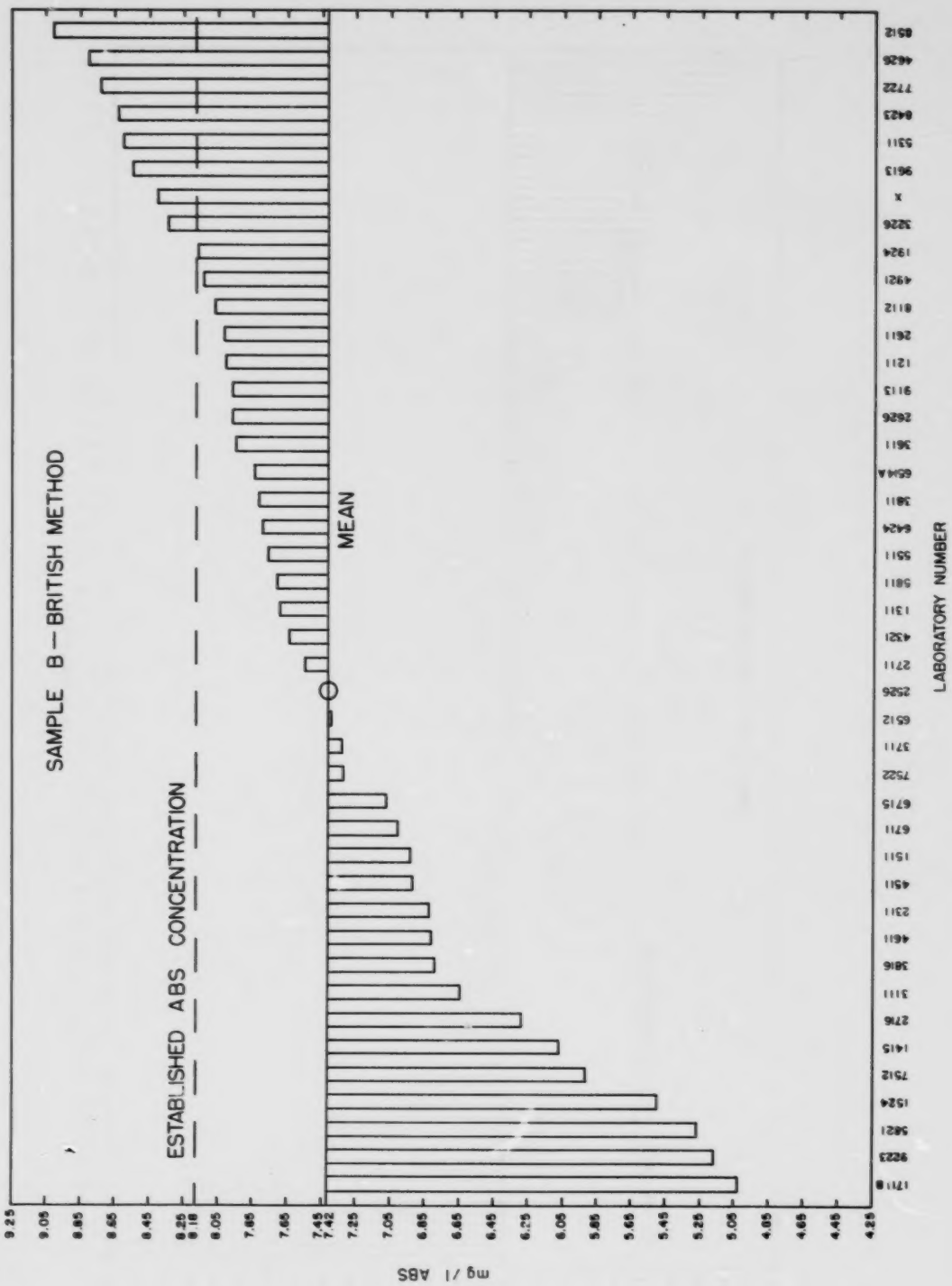
The relative merits of the three methods are clear-cut. They failed to recover all of the ABS, as mean values for each were less than the established concentration. The British Method produced better accuracy and precision; the low and high results also provided the narrowest range. The Standard Method ranked second in performance.

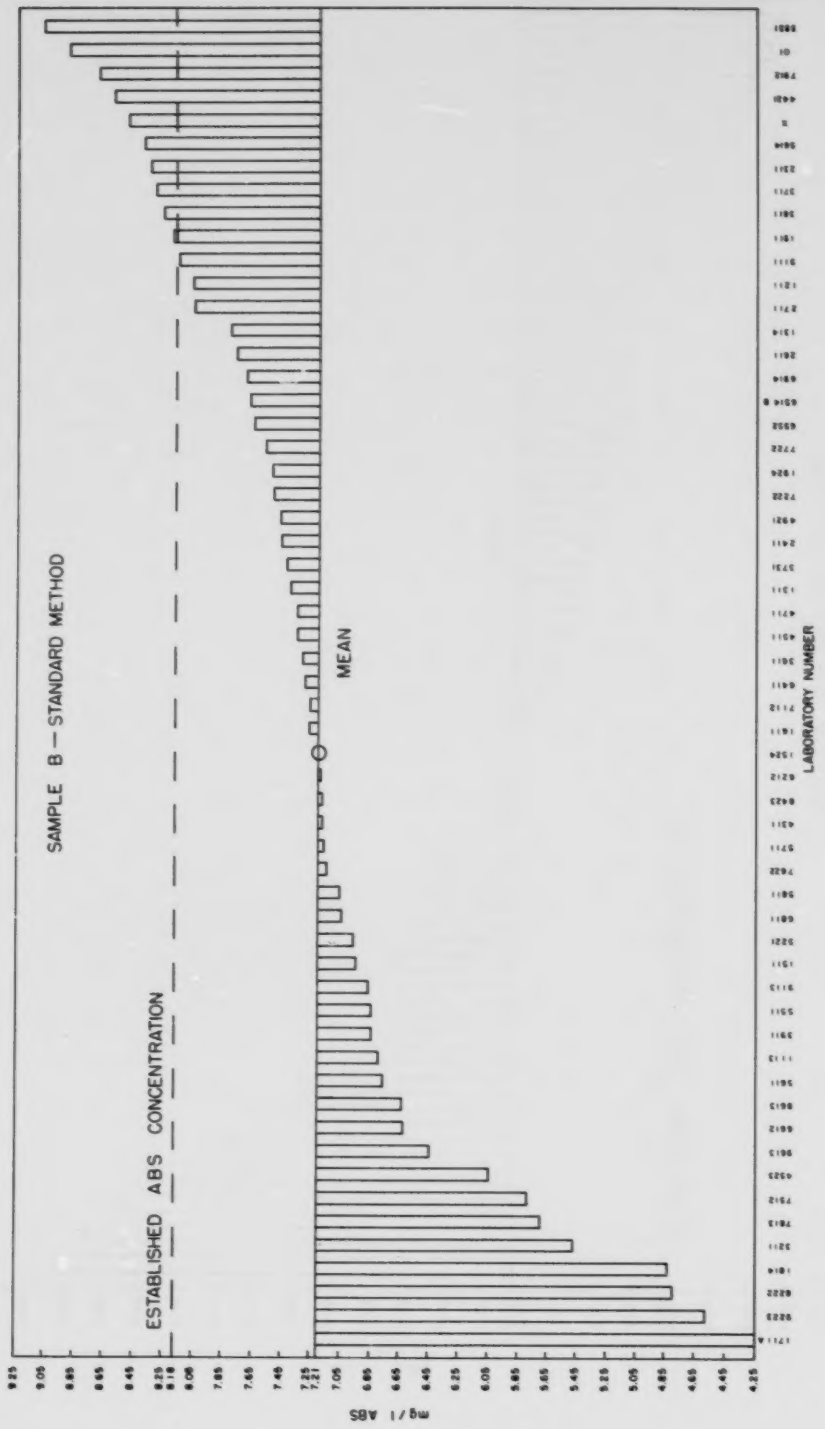
Within the limits imposed by this study, the British Method is the method of choice for analysis of ABS in sewage. The Standard Method may be expected to produce results within 1 mg/l of the actual concentration at this level. The SEC Method probably should be used only as a screening procedure when speed is the prime requisite.

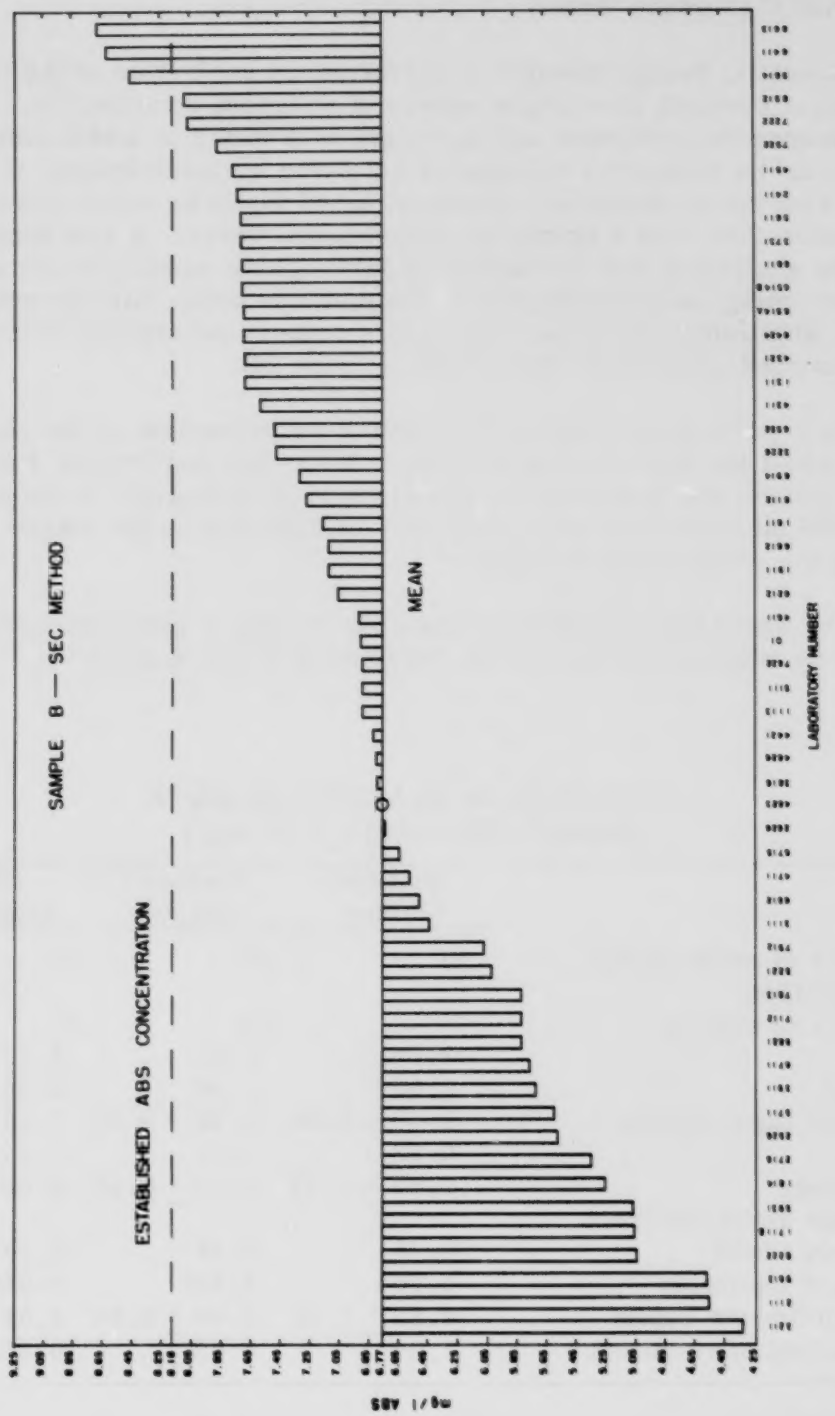

PROBABILITY CURVE FOR
SAMPLE B – BRITISH METHOD
mg/l ABS
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
88.330
480
plotting interval = 100/50 = 2.000


PROBABILITY CURVE FOR
SAMPLE B – STANDARD METHOD
mg/l ABS
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
99.99
99.9
99.8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01
323
1.64
plotting interval = 100/61 = 1.639


PROBABILITY CURVE FOR
SAMPLE B – SEC METHOD
mg/l ABS
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
14.70
84.17
plotting interval = 100/61 = 1.639


SAMPLE B — BRITISH METHOD
ESTABLISHED ABS CONCENTRATION
MEAN
mg / l ABS
LABORATORY NUMBER


SAMPLE B — STANDARD METHOD
ESTABLISHED ABS CONCENTRATION
MEAN
LABORATORY NUMBER
mg/l ABS


SAMPLE B — SEC METHOD
ESTABLISHED ABS CONCENTRATION
MEAN
LABORATORY NUMBER
mg/l ABS

SAMPLE C (Surface Water)

Sample C design provided a performance evaluation of the three analytical methods on surface waters of different composition. By determining the precision and accuracy with which an added amount of ABS could be measured in samples collected by participants, it was hoped that the performance values obtained would be more universally applicable than with a synthetic or sterilized water. It was hoped also that the analytical data furnished by participants would provide a means for evaluating the performance of the methods under various conditions of pH, alkalinity, hardness, and solids content; no significant trend could be discerned from these data (Table 1, page 24).

Each participant collected a surface water sample of his choice and determined the ABS already present. A sterile, hard-glass Jeb tube of ABS solution was provided for introduction of 2.60 mg/l to the sample. The ARS laboratory found no evidence of ABS loss in the sterile vials during the entire study period.

The summary of statistical data for Sample C gives the values obtained by analysis of the results reported in Table 4, page 68.

SUMMARY OF STATISTICAL DATA
Amount ABS Added - 2.60 mg/l

	British Method	Standard Method	SEC Method
Number of participants per method	40	53	53
Number of results	40	53	53
Mean	2.59	2.60	2.56
Median	2.60	2.56	2.55
Low and high results	2.15 - 2.98	2.28 - 3.29	1.96 - 3.34
Range	0.83	1.01	1.38
50% range	2.60 $\pm$ 0.13	2.60 $\pm$ 0.15	2.60 $\pm$ 0.14
Average deviation from amount added	0.16	0.17	0.19
Standard deviation	0.204	0.232	0.260
95% confidence limits	2.59 $\pm$ 0.06	2.60 $\pm$ 0.06	2.56 $\pm$ 0.07
Coefficient of variation	7.9%	8.9%	10.1%

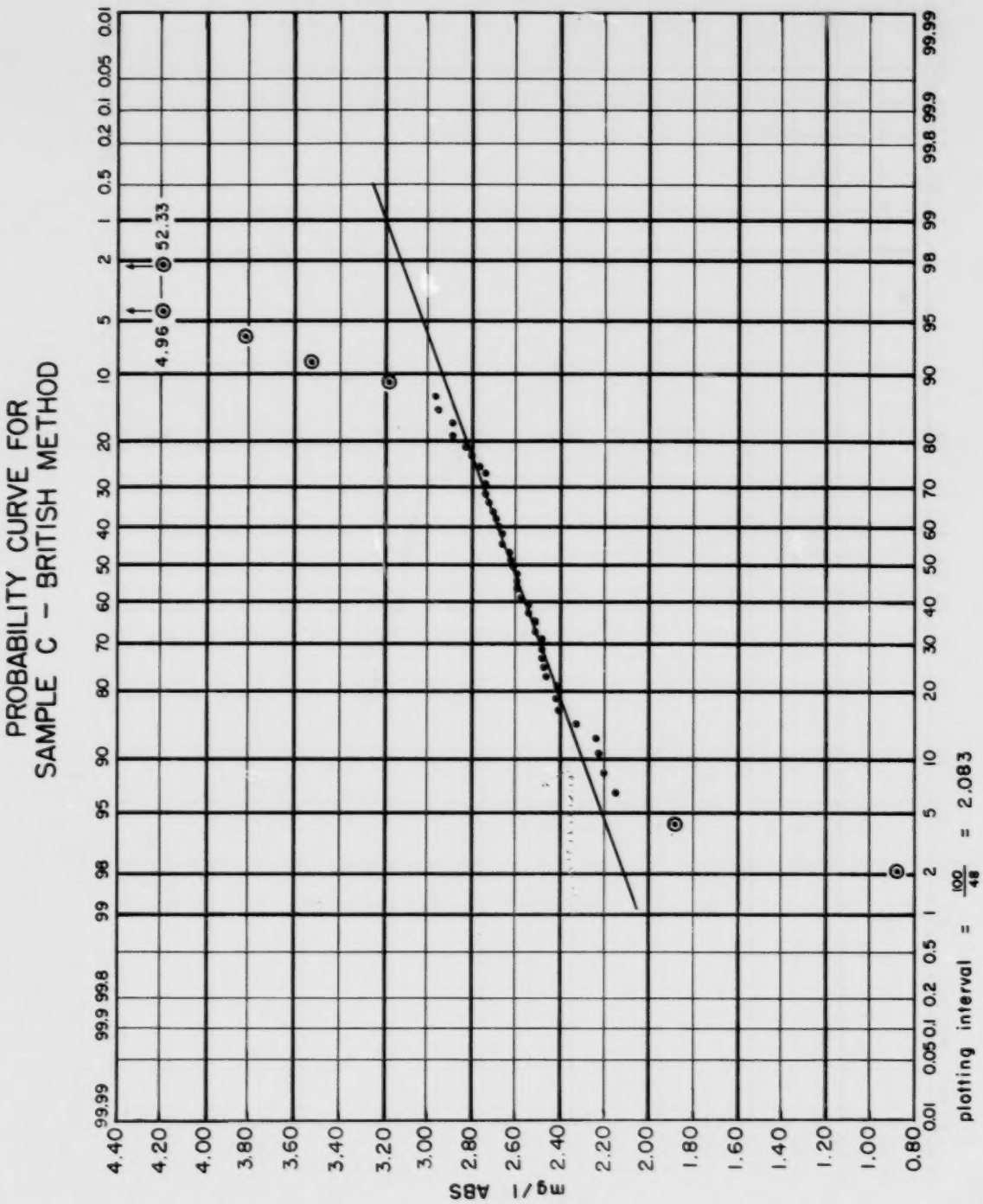
It was necessary to reject 17 outliers - seven for the British Method and 5 each for the Standard and SEC Methods. The probability curves appear on pages 25, 26, and 27, and the bar graphs, indicating the distribution of all results reported by participants, on pages 28, 29, and 30.

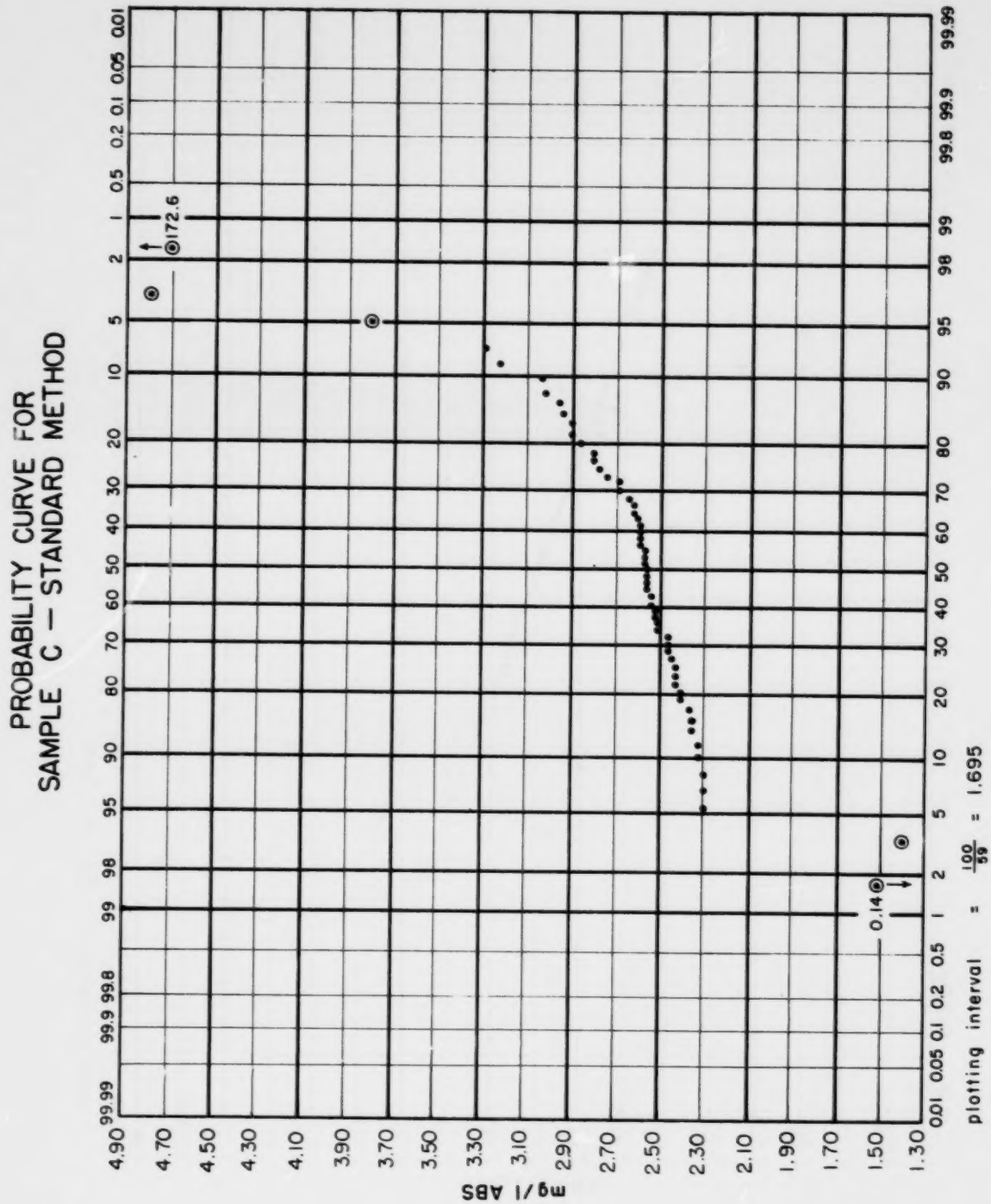
All three methods produced satisfactory results on the vast array of sample waters. Eighty-three different surface waters were collected by the participating laboratories, from ponds, reservoirs, rivers, lakes, and streams all the way from Taiwan to England, and from the four corners of the United States. The mean and median values all agreed closely with the amount of ABS added. The more accurate 50% of the results, by any method, deviated from the amount added by not more than $\pm$ 0.15 mg/l. Another accuracy parameter, average deviation, showed a maximum value of 0.19 mg/l. All methods produced greater accuracy than precision, as shown by the variation in the standard deviations from 0.204 to 0.260.

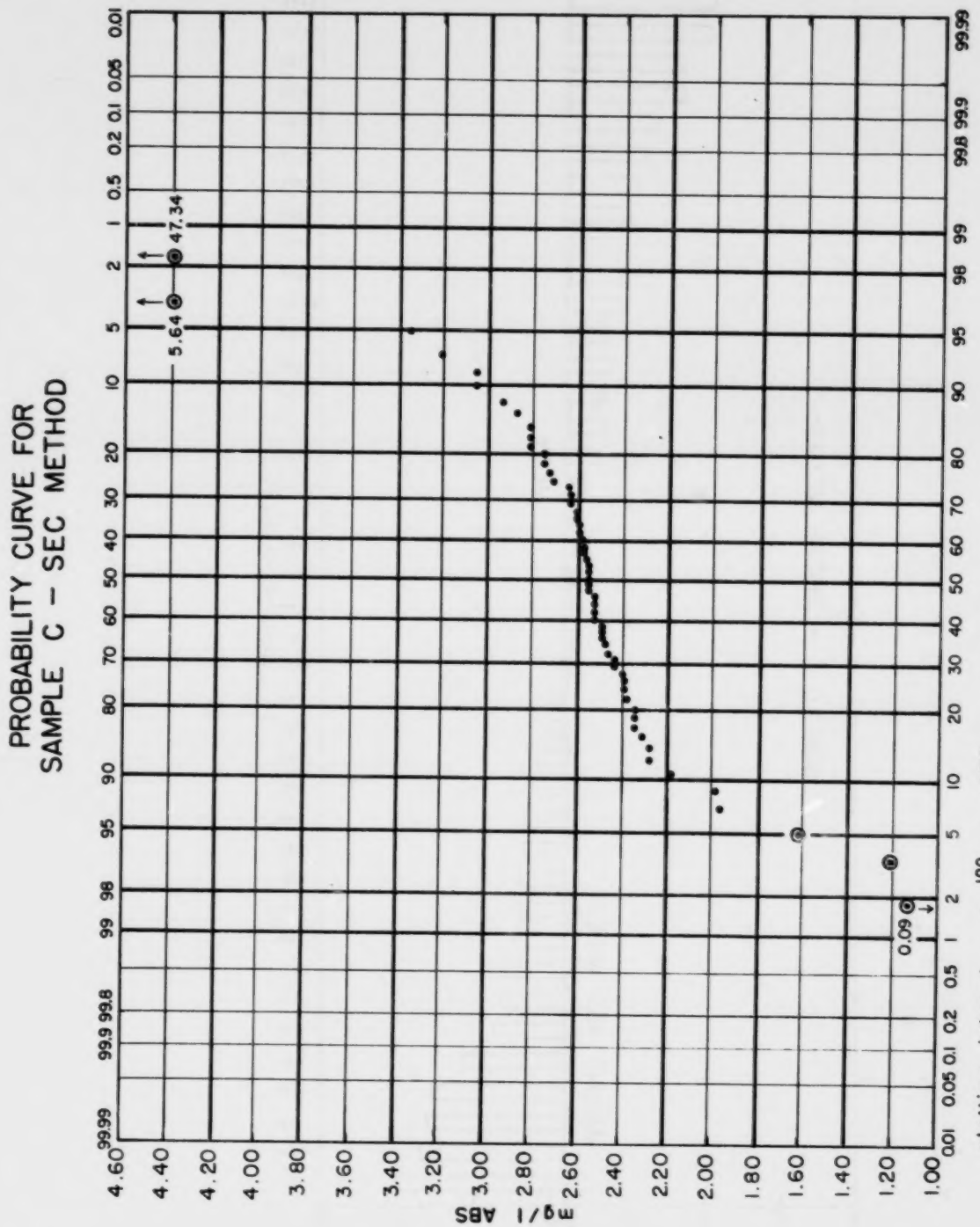
Considering all statistical parameters, the British and Standard Methods yielded slightly better precision and accuracy than did the SEC Method. Nevertheless, with a 95% confidence limit of 2.56 $\pm$ 0.07, the SEC Method is unquestionably an adequate procedure for surface waters except when extremely accurate research data are sought.

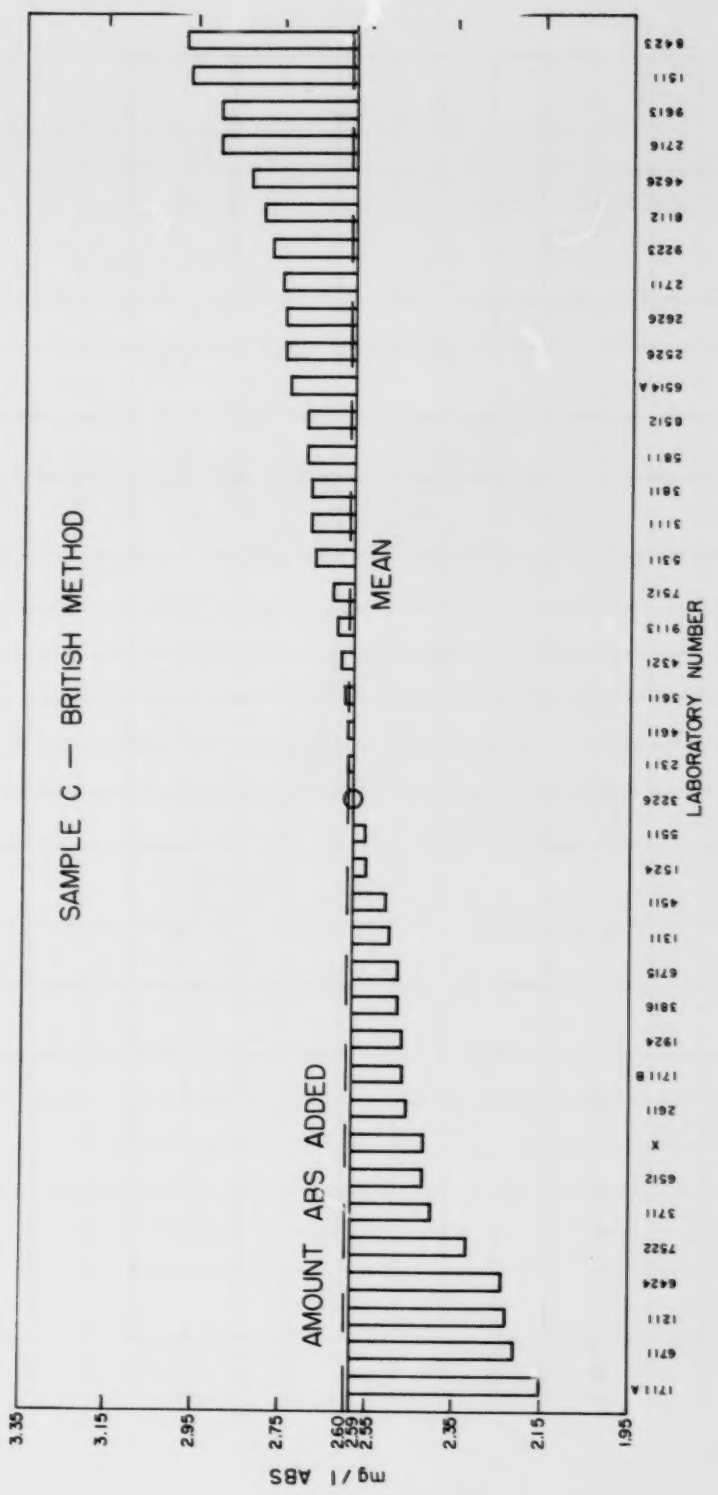
Table 1. CHEMICAL DATA REPORTED BY PARTICIPANTS FOR SAMPLE C

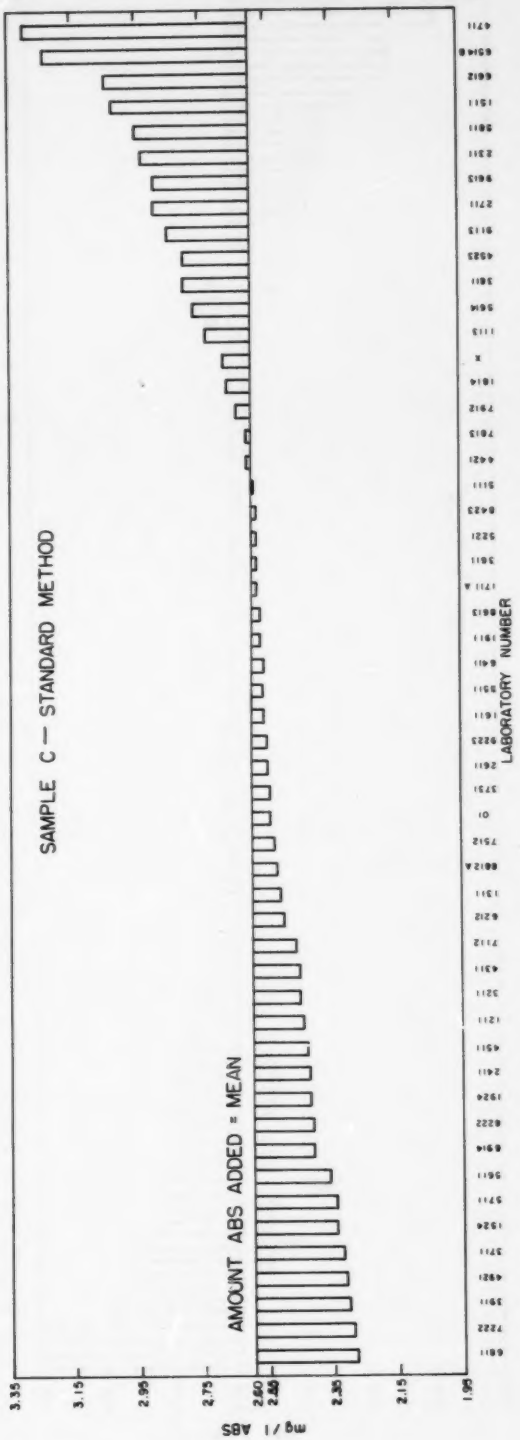
	Mean			Standard deviation			Number of results		
	British	St'd	SEC	British	St'd	SEC	British	St'd	SEC
Total Alkalinity									
Below 50 mg/l	2.70	2.57	2.52	0.182	0.228	0.221	11	16	14
50 - 100 mg/l	2.61	2.80	2.65	-	-	0.385	3	2	5
Above 100 mg/l	2.51	2.56	2.60	0.203	0.187	0.274	10	18	11
pH									
pH 6.0 - 7.0	2.74	2.63	2.60	0.134	0.223	0.138	9	10	12
pH 7.1 - 8.0	2.54	2.60	2.60	0.206	0.264	0.401	14	24	16
Above pH 8.0	2.50	2.72	2.55	0.211	0.263	0.256	5	4	9
Total Solids									
Below 200 mg/l	2.71	2.62	2.52	0.140	0.231	0.119	11	10	10
200 - 500 mg/l	2.51	2.86	2.71	-	0.307	0.505	2	7	5
Above 500 mg/l	-	2.80	2.84	-	-	-	0	2	2
Total Hardness									
Below 100 mg/l	2.64	2.58	2.54	0.205	0.215	0.145	19	17	15
100 - 300 mg/l	2.54	2.60	2.56	0.212	0.238	0.372	6	17	11
Above 300 mg/l	2.49	2.59	2.81	-	-	-	3	3	3

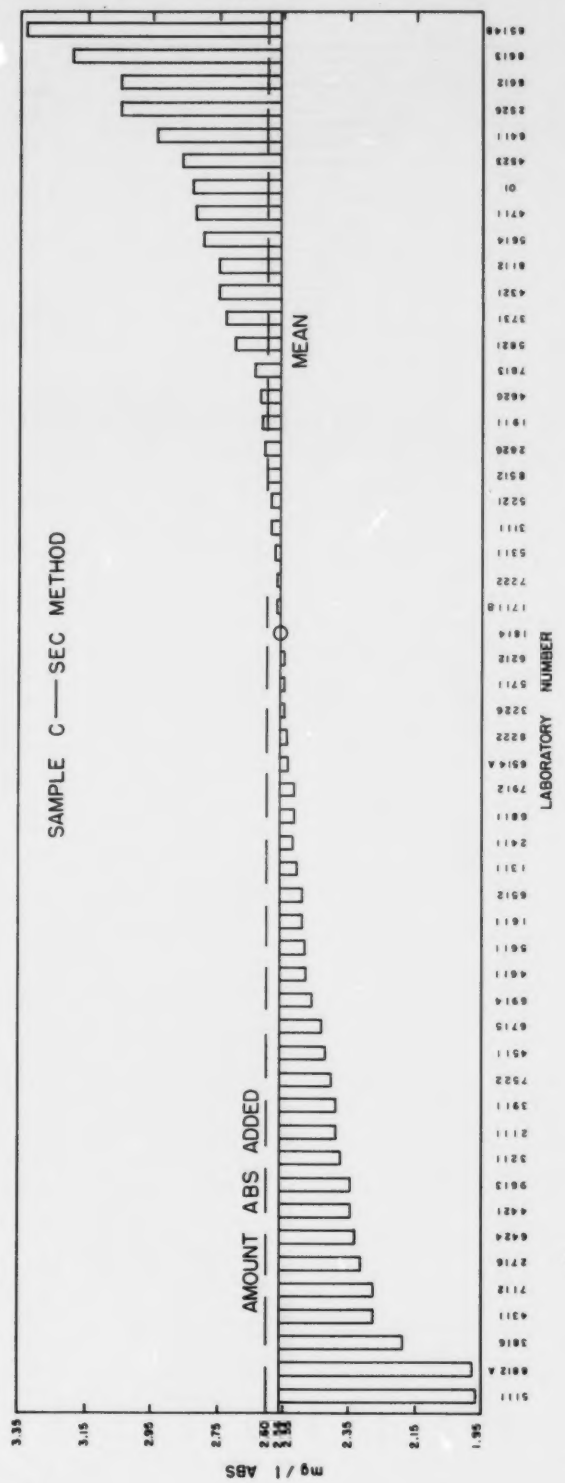

PROBABILITY CURVE FOR
SAMPLE C - BRITISH METHOD
mg/l ABS
4.40
4.20
4.00
3.80
3.60
3.40
3.20
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
4.96
52.33
plotting interval = 100/48 = 2.083


PROBABILITY CURVE FOR
SAMPLE C — STANDARD METHOD
mg/l ABS
4.90
4.70
4.50
4.30
4.10
3.90
3.70
3.50
3.30
3.10
2.90
2.70
2.50
2.30
2.10
1.90
1.70
1.50
1.30
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
172.6
0.14
plotting interval = 100/59 = 1.695


PROBABILITY CURVE FOR
SAMPLE C - SEC METHOD
mg/l - ABS
plotting interval = 100/59 = 1.695
5.64
47.34
0.09


SAMPLE C — BRITISH METHOD
MEAN
AMOUNT ABS ADDED
LABORATORY NUMBER
mg / l ABS
3.35
3.15
2.95
2.75
2.60
2.59
2.55
2.35
2.15
1.95
8423
1511
9613
2716
4626
8112
9223
2711
2626
2526
6514 A
0512
5811
3811
3111
5311
7512
9113
4321
3611
4611
2311
3226
5511
1524
4511
1311
6715
3816
1924
1711 B
2611
X
6512
3711
7522
6424
1211
6711
1711 A


SAMPLE C — STANDARD METHOD
AMOUNT ABS ADDED = MEAN
LABORATORY NUMBER
mg/l ABS
3.35
3.15
2.95
2.75
2.60
2.55
2.35
2.15
1.95


SAMPLE C — SEC METHOD
MEAN
AMOUNT ABS ADDED
LABORATORY NUMBER
mg / l ABS
3.35
3.15
2.95
2.75
2.60
2.55
2.35
2.15
1.95

COMMENTS OF PARTICIPANTS

The abundant comments offered by participants contain pertinent observations. They are listed below by method. Other observations, such as relative difficulty and time requirements, need no discussion.

British Method

The method is too long for routine use.

To save time, the reagents could be extracted in bulk.

The method removes positive interferences.

Three extractions are insufficient for high ABS concentrations.

The large amount of chloroform used makes the method costly.

The method causes more emulsification than the others.

Standard Method

Absorbance should be measured at the peak wavelength as determined by the analyst.

The working standard should be prepared fresh each day.

The instruction "rock vigorously" is not specific.

No time is quoted for phase-separation.

No mention is made of the stability of the dye complex.

No mention is made of how long samples may be stored before analysis.

The wash step carries color through.

Some blue color adsorbs on glass wool.

There is no provision for removal of chlorine.

One minute of shaking is better than a half minute.

Emulsification was encountered with the sewage sample.

SEC Procedure

The method gives lower results than the British Method.

Lower results were obtained with a 125 ml separatory funnel than with a 250 ml funnel.

Emulsification was encountered with the sewage sample.

The specified volume of chloroform is insufficient for high ABS concentration.

The method is susceptible to interference.

No provision is made for removal of chlorine.

One minute of shaking is better than a half minute.

No time is quoted for phase-separation.

No mention is made of how long samples may be stored before analysis.

Applicable to all three methods

No difference was noted between distilled and undistilled chloroform.

No difference was noted between ACS and technical chloroform.

Cotton is more effective than glass wool for water removal, but adsorbs more blue color, even when rinsed.

Absorbance readings are initially unstable and decrease before stabilizing.

Emulsions are easily broken.

Sodium sulfate is preferable to cotton for water removal.

Spectrophotometer cells should be rinsed with chloroform after each reading.

Excessive time causes fading and evaporation.

The degree of shaking the sample container receives is a major factor.

Size and uniformity of cotton pledgets is important.

ARS Laboratory Observation

The experience of the Analytical Reference Service Laboratory indicates that the degree of shaking given the sample container is important because of the conflicting effects of adsorption and foaming. Adsorption

of the methylene blue complex on glassware and cuvettes is a significant source of error. The presence of detergent residues on glassware can be critical; it may well have been a cause of the high outliers. Reagent quality is a factor in determining the need for lengthy cleanup procedures. Precision is largely dependent on standardization of technique. Many questions have been posed as a result of the study that will require considerable research to answer adequately.

SUMMARY AND CONCLUSIONS

This second surfactant study permitted evaluation of three widely used analytical methods. The 83 cooperating agencies provided nearly 2,000 results.

Any of the three methods is satisfactory for the determination of ABS in waters containing no interferences. Fifty percent of all cooperating agencies obtained results within $\pm$ 0.04 mg/l of the established concentration regardless of method used.

Within the limits imposed by the study, the British Method is the method of choice for analysis of ABS in sewage. The Standard Method may be expected to produce results within 1 mg/l of the actual concentration at this level of ABS. The SEC Method is the least accurate, but does have the advantages of speed and simplicity.

Considering all statistical parameters, the British and Standard Methods yielded slightly better precision and accuracy than did the SEC Method for surface waters. Nevertheless, with a 95% confidence limit of 2.56 $\pm$ 0.07, the SEC Method is unquestionably an adequate procedure for surface waters except when extremely accurate research data are sought. For the entire study, at least half of the participants had an average percent deviation within laboratories of less than 3%.

TABULATION OF RESULTS

Table 2. SURFACTANT - Sample A

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
6811	0.30 0.26 0.26	0.27	6.2	31.7	Standard
6514A	0.24 0.24 0.35	0.28	17.8	30.8	SEC
3911	0.29 0.27 0.31	0.29	4.6	27.5	SEC
4421	0.36 0.32 0.23	0.30	16.7	24.2	SEC
1711A	0.32 0.30 0.31	0.31	2.1	22.5	British
1711A	0.30 0.32 0.32	0.31	3.2	21.7	Standard
8112	0.24 0.40 0.30	0.31	18.3	21.7	British
8222	0.32 0.30 0.33	0.32	3.1	20.8	SEC
1524	0.32 0.41 0.27	0.33	15.2	18.3	Standard
2111	0.30 0.38 0.30	0.33	11.1	18.3	SEC

Water Surfactant Number 2

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
8112	0.30 0.34 0.34	0.33	5.0	18.3	SEC
8812A	0.30 0.36 0.34	0.33	7.1	16.7	SEC
7512	0.36 0.31 0.36	0.34	6.9	14.2	Standard
5511	0.33 0.36	0.35	4.3	13.8	British
6514A	0.34 0.38 0.34	0.35	4.8	11.7	British
7912	0.50 0.18 0.37	0.35	32.4	29.2	SEC
9223	0.34 0.34 0.37	0.35	3.8	12.5	Standard
3211	0.34 0.36 0.37	0.36	2.8	10.8	SEC
4611	0.35 0.37 0.37	0.36	2.8	9.2	SEC
6552	0.34 0.37	0.36	4.2	11.2	Standard
6715	0.34 0.37 0.36	0.36	2.8	10.8	SEC

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
1415	0.38 0.38 0.36	0.37	2.7	6.7	British
1415	0.35 0.37 0.40	0.37	4.5	6.7	Standard
2611	0.40 0.31 0.41	0.37	11.7	8.3	British
2626	0.36 0.37 0.38	0.37	1.8	7.5	SEC
4921	0.37 0.37 0.38	0.37	0.9	6.7	British
5711	0.35 0.41 0.36	0.37	6.3	8.3	Standard
6512	0.33 0.38 0.39	0.37	6.3	8.3	British
6715	0.34 0.40 0.36	0.37	6.3	8.3	British
7912	0.40 0.31 0.41	0.37	11.7	8.3	Standard
1924	0.38 0.38 0.38	0.38	0	5.0	British

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
1924	0.37 0.38 0.38	0.38	0.9	5.8	Standard
2611	0.38 0.40 0.35	0.38	4.4	5.8	Standard
3711	0.37 0.39 0.39	0.38	2.6	4.2	British
5511	0.34 0.43	0.38	11.8	11.2	Standard
6914	0.38 0.38 0.38	0.38	0	5.0	Standard
7512	0.38 0.39 0.38	0.38	0.9	4.2	British
8222	0.39 0.38 0.38	0.38	0.9	4.2	Standard
8613	0.36 0.40 0.38	0.38	3.5	5.0	SEC
9223	0.36 0.38 0.41	0.38	4.4	5.8	British
3211	0.40 0.38 0.38	0.39	2.6	3.3	Standard

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
3611	0.36 0.41	0.39	6.4	6.2	Standard
4511	0.38 0.40 0.40	0.39	2.6	1.7	British
4611	0.38 0.39 0.40	0.39	1.7	2.5	British
4921	0.39 0.39 0.39	0.39	0	2.5	Standard
5611	0.40 0.36 0.40	0.39	4.3	3.3	Standard
6411	0.38 0.38 0.40	0.39	2.6	3.3	Standard
7222	0.43 0.38 0.36	0.39	6.8	7.5	Standard
7622	0.40 0.38 0.38	0.39	2.6	3.3	SEC
1911	0.39 0.41 0.40	0.40	1.7	1.7	Standard
1911	0.39 0.40 0.41	0.40	1.7	1.7	SEC

Water Surfactant Number 2

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
2411	0.42 0.38 0.39	0.40	4.2	4.2	Standard
4321	0.40 0.40	0.40	0	0	British
4523	0.40 0.40 0.40	0.40	0	0	Standard
5811	0.41 0.39 0.40	0.40	1.7	1.7	British
5931	0.40 0.40 0.40	0.40	0	0	SEC
6424	0.40 0.39 0.41	0.40	1.7	1.7	British
7622	0.39 0.38 0.42	0.40	4.2	4.2	Standard
8512	0.40	0.40	-	0	British
8613	0.41 0.39 0.41	0.40	2.5	2.5	Standard
1311	0.39 0.41 0.43	0.41	3.2	4.2	British
1311	0.42 0.41 0.41	0.41	0.8	3.3	Standard

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
1611	0.42 0.38 0.43	0.41	4.9	5.8	SEC
2411	0.41 0.40 0.41	0.41	0.8	1.7	SEC
3811	0.41 0.41 0.42	0.41	0.8	3.3	British
4511	0.41 0.41 0.41	0.41	0	2.5	Standard
4511	0.38 0.42 0.42	0.41	4.0	5.0	SEC
4626	0.43 0.42 0.39	0.41	4.0	5.0	British
4626	0.38 0.43 0.43	0.41	5.7	6.7	SEC
5614	0.42 0.40	0.41	2.4	2.5	Standard
5811	0.39 0.45 0.39	0.41	6.5	5.8	Standard
6552	0.42 0.40 0.42	0.41	2.4	3.3	SEC

Water Surfactant Number 2

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
6914	0.42 0.41 0.41	0.41	0.8	3.3	SEC
7722	0.42 0.39 0.41	0.41	2.4	3.3	Standard
7813	0.40 0.40 0.42	0.41	2.4	1.7	SEC
9113	0.41 0.41 0.42	0.41	0.8	3.3	British
9113	0.42 0.41 0.41	0.41	0.8	3.3	Standard
9613	0.40 0.41 0.41	0.41	0.8	1.7	SEC
unidenti-fied	0.45 0.43 0.35	0.41	9.8	10.8	Standard
01	0.40 0.45 0.40	0.42	5.6	4.2	SEC
1311	0.42 0.42 0.42	0.42	0	5.0	SEC
1314	0.40 0.44	0.42	4.8	5.0	British

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
1814	0.41 0.43 0.43	0.42	2.4	5.8	Standard
1814	0.40 0.44 0.43	0.42	4.0	5.8	SEC
2711	0.42 0.40 0.43	0.42	2.4	4.2	Standard
3226	0.44 0.43 0.40	0.42	4.0	5.8	British
3731	0.48 0.34 0.44	0.42	12.7	15.0	Standard
4421	0.42 0.42 0.42	0.42	0	5.0	Standard
4523	0.42 0.42 0.41	0.42	0.8	4.2	SEC
5311	0.41 0.43 0.42	0.42	1.6	5.0	SEC
6411	0.43 0.37 0.45	0.42	7.1	9.2	SEC
6512	0.41 0.45 0.41	0.42	4.0	5.8	SEC

Water Surfactant Number 2

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
6612	0.40 0.43 0.43	0.42	3.2	5.0	Standard
7222	0.44 0.43 0.40	0.42	4.0	5.8	SEC
1211	0.43 0.44 0.43	0.43	0.8	8.3	British
1211	0.43 0.43 0.42	0.43	0.8	6.7	Standard
1711B	0.40 0.40 0.48	0.43	8.5	6.7	British
2711	0.43 0.43 0.42	0.43	0.8	6.7	British
3111	0.41 0.46 0.43	0.43	3.9	8.3	SEC
3226	0.41 0.45 0.42	0.43	3.9	6.7	SEC
3611	0.44 0.43 0.43	0.43	0.8	8.3	British
5311	0.40 0.48 0.40	0.43	8.5	6.7	British

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
5614	0.44 0.42 0.42	0.43	2.3	6.7	SEC
7112	0.42 0.43 0.44	0.43	1.5	7.5	SEC
7813	0.40 0.48 0.42	0.43	7.0	8.3	Standard
2626	0.46 0.45 0.41	0.44	4.5	10.0	British
3111	0.45 0.47 0.40	0.44	6.0	10.0	British
4321	0.42 0.45 0.44	0.44	2.3	9.2	SEC
6514B	0.44 0.45 0.44	0.44	0.8	10.8	SEC
6711	0.39 0.46 0.46	0.44	6.8	10.8	SEC
7722	0.45 0.44 0.44	0.44	0.8	10.8	British
8512	0.40 0.48	0.44	9.1	10.0	SEC

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
unidenti-fied	0.44 0.43 0.45	0.44	1.5	10.0	British
1113	0.43 0.43 0.48	0.45	5.2	11.7	Standard
1511	0.44 0.45 0.45	0.45	0.7	11.7	British
1611	0.40 0.40 0.55	0.45	14.8	12.5	Standard
1711B	0.46 0.44 0.46	0.45	2.2	13.3	SEC
3711	0.43 0.45 0.48	0.45	3.7	13.3	Standard
5311	0.46 0.44 0.45	0.45	1.5	12.5	Standard
6212	0.46 0.44 0.44	0.45	2.2	11.7	Standard
6212	0.44 0.46 0.46	0.45	2.2	13.3	SEC
6514B	0.45 0.45 0.44	0.45	0.7	11.7	Standard

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
1113	0.46 0.46 0.47	0.46	0.7	15.8	SEC
3816	0.46	0.46	-	15.0	SEC
3911	0.44 0.59 0.35	0.46	18.8	23.3	Standard
5821	0.45 0.46 0.46	0.46	0.7	14.2	SEC
6612	0.45 0.45 0.48	0.46	2.9	15.0	SEC
6811	0.50 0.46 0.42	0.46	5.8	15.0	SEC
8812A	0.46 0.46 0.45	0.46	0.7	14.2	Standard
5611	0.36 0.52 0.54	0.47	16.3	25.0	SEC
5711	0.47 0.43 0.50	0.47	5.0	16.7	SEC
6711	0.55 0.36 0.49	0.47	14.9	23.3	British

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
9613	0.46 0.46 0.50	0.47	3.5	18.3	British
2311	0.48 0.48 0.47	0.48	0.7	19.2	British
3811	0.49 0.47 0.48	0.48	1.4	20.0	Standard
5221	0.48 0.47 0.49	0.48	1.4	20.0	SEC
01	0.50 0.48 0.50	0.49	2.0	23.3	Standard
1524	0.53 0.53 0.40	0.49	11.6	21.7	British
5221	0.50 0.49 0.48	0.49	1.4	22.5	Standard
5821	0.50 0.50 0.46	0.49	3.4	21.7	British
8423	0.49 0.47 0.50	0.49	2.0	21.7	British
2311	0.50 0.50 0.50	0.50	0	25.0	Standard

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
4311	0.49 0.50 0.50	0.50	0.7	24.2	SEC
7522	0.51 0.50 0.49	0.50	1.3	25.0	British
9613	0.45 0.49 0.56	0.50	8.0	25.0	Standard
4711	0.50 0.49 0.55	0.51	4.6	28.3	Standard
4711	0.53 0.49 0.50	0.51	3.3	26.7	SEC
7522	0.51 0.51 0.50	0.51	0.6	26.7	SEC
1314	0.52 0.52	0.52	0	30.0	Standard
8423	0.56 0.54 0.56	0.55	1.8	38.3	Standard
5111	0.56 0.57 0.56	0.56	0.6	40.8	SEC

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
6424	0.54 0.56 0.57	0.56	1.8	39.2	SEC
5111	0.60 0.58 0.52	0.57	5.3	41.7	Standard
3731	0.63 0.48 0.64	0.58	12.1	45.8	SEC
1511	0.72 0.62 0.52	0.62	10.7	55.0	Standard

Table 3. SURFACTANT - Sample B

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
1711A	4.19 4.31 4.24	4.25	1.0	48.1	Standard
3211	4.25 4.40 4.35	4.33	1.3	47.0	SEC
2111	3.12 5.56 5.00	4.56	21.0	44.2	SEC
9613	4.45 4.90 4.35	4.57	4.9	44.2	SEC
9223	4.40 4.30 5.05	4.58	6.8	44.0	Standard
8222	4.66 4.75 5.00	4.80	2.7	41.3	Standard
1814	4.52 5.01 4.96	4.83	4.3	41.0	Standard
1711B	4.90 5.00 5.20	5.03	2.2	38.5	British
8222	5.16 5.25 4.75	5.05	4.0	38.2	SEC
1711B	5.10 5.00 5.10	5.06	0.9	38.0	SEC

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
5931	5.00 5.00 5.20	5.07	1.8	38.0	SEC
9223	4.90 5.30 5.30	5.17	3.4	36.8	British
1814	5.23 5.33 5.22	5.26	0.9	35.7	SEC
5821	5.00 5.20 5.60	5.27	4.2	35.6	British
2716	4.48 4.60 6.96	5.35	20.1	34.6	SEC
3211	5.70 5.50 5.20	5.47	3.2	33.1	Standard
1524	5.51 5.51 5.49	5.50	0.2	32.7	British
2526	6.00 5.50 5.25	5.58	5.0	31.7	SEC
5711	4.80 5.20 6.80	5.60	14.3	31.5	SEC
7813	5.65 5.80 5.65	5.70	1.2	30.3	Standard

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
3911	5.90 5.30 6.00	5.73	5.0	29.9	SEC
6711	5.45 6.13 5.72	5.77	4.2	29.5	SEC
7512	5.79 5.67 5.92	5.79	1.4	29.2	Standard
5821	5.80 5.80 5.90	5.83	0.7	28.7	SEC
7112	5.90 5.60 6.00	5.83	2.7	28.7	SEC
7813	5.65 6.10 5.75	5.83	3.0	28.7	SEC
7512	5.92 5.92 5.92	5.92	0	27.6	British
5221	6.20 5.80 6.10	6.03	2.6	26.2	SEC
4523	6.05 6.10 6.00	6.05	0.5	26.0	Standard
1415	6.25 6.15 5.80	6.07	2.9	25.8	British

Water Surfactant Number 2

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
7912	5.45 6.15 6.65	6.08	7.0	25.6	SEC
2716	6.20 6.28 6.40	6.29	1.1	23.1	British
3111	6.40 6.55 6.40	6.45	1.0	21.1	SEC
9613	7.80 5.40 6.15	6.45	14.0	21.1	Standard
6512	6.75 6.40 6.40	6.52	2.4	20.3	SEC
4711	6.50 6.50 6.75	6.58	1.7	19.5	SEC
6612	6.80 6.50 6.60	6.63	1.6	18.9	Standard
8613	6.65 6.63 6.65	6.64	0.2	18.8	Standard
3111	6.70 6.55 6.70	6.65	1.0	18.7	British
6715	6.94 6.14 6.88	6.65	5.2	18.6	SEC

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
2626	6.30 6.90 7.05	6.75	4.4	17.5	SEC
4523	6.83 6.73 6.73	6.76	0.6	17.3	SEC
5611	6.70 7.40 6.20	6.77	6.2	17.3	Standard
1113	7.00 6.00 7.40	6.80	7.8	16.9	Standard
3816	6.80	6.80	-	16.9	British
3816	6.80	6.80	-	16.9	SEC
4626	6.86 6.81 6.75	6.81	0.5	16.8	SEC
4611	5.90 6.10 8.45	6.82	16.0	18.9	British
2311	6.75 7.00 6.75	6.83	1.6	16.5	British
4421	7.60 6.45 6.45	6.83	7.5	16.4	SEC
3911	7.35 6.35 6.85	6.85	4.9	16.2	Standard

Water Surfactant Number 2

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
5511	6.80 6.90	6.85	0.7	16.2	Standard
9113	6.70 7.00 6.90	6.87	1.6	16.0	Standard
1113	7.00 6.80 6.90	6.90	1.0	15.6	SEC
5111	6.90 6.91 6.88	6.90	0.1	15.7	SEC
7622	7.30 7.30 6.10	6.90	7.7	15.6	SEC
01	7.00 7.00 6.75	6.92	1.6	15.4	SEC
4511	6.80 7.15 6.85	6.93	2.1	15.2	British
4611	6.95 6.95 6.90	6.93	0.3	15.2	SEC
1511	7.06 6.87 6.88	6.94	1.2	15.2	British
1511	7.00 6.85 7.00	6.95	1.0	15.0	Standard

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
5221	7.05 6.90 6.95	6.97	0.8	14.8	Standard
6711	7.18 6.67 7.18	7.01	3.2	14.3	British
6811	6.90 7.12 7.12	7.05	1.4	13.8	Standard
5811	6.96 6.96 7.27	7.06	1.9	13.6	Standard
6212	7.00 7.00 7.20	7.07	1.3	13.6	SEC
6715	7.68 6.75 6.82	7.08	5.6	13.4	British
1911	6.90 7.35 7.15	7.13	2.2	12.8	SEC
6612	7.00 7.20 7.20	7.13	1.3	12.8	SEC
7622	7.05 7.30 7.10	7.15	1.4	12.6	Standard
1611	7.50 7.60 6.40	7.17	7.1	12.4	SEC

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
5711	7.30 7.10 7.10	7.17	1.2	12.4	Standard
4311	7.25 7.10 7.18	7.18	0.7	12.3	Standard
8423	7.34 7.09 7.12	7.18	1.4	12.2	Standard
6212	7.20 7.20 7.20	7.20	0	12.0	Standard
1524	6.66 7.44 7.54	7.21	5.1	11.8	Standard
1611	7.40 7.00 7.40	7.27	2.4	11.2	Standard
7112	7.30 7.30 7.20	7.27	0.6	11.2	Standard
8112	6.50 7.50 7.85	7.28	7.2	11.0	SEC
6411	7.40 7.50 7.10	7.30	2.3	10.3	Standard
3611	7.55 7.38 7.03	7.32	2.6	10.5	Standard

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
6914	7.30 7.40 7.30	7.33	0.6	10.3	SEC
7522	7.10 7.40 7.50	7.33	2.1	10.3	British
3711	7.34 7.34 7.35	7.34	0.0	10.2	British
4511	7.40 7.30 7.35	7.35	0.4	10.1	Standard
4711	7.02 7.52 7.52	7.35	3.0	10.1	Standard
1311	7.40 7.40 7.40	7.40	0	9.5	Standard
6512	7.58 6.90 7.75	7.41	4.6	9.4	British
2526	7.25 7.60 7.40	7.42	1.6	9.3	British
3731	8.35 6.85 7.10	7.43	8.2	10.5	Standard
2411	7.47 7.40 7.53	7.47	0.6	8.7	Standard

Water Surfactant Number 2

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
4921	7.49 7.49 7.44	7.47	0.3	8.6	Standard
3226	7.40 7.95 7.40 7.20	7.49	3.1	8.5	SEC
6552	7.75 7.50 7.25	7.50	2.2	8.3	SEC
7222	7.64 7.60 7.32	7.52	1.8	8.1	Standard
1924	7.59 7.40 7.60	7.53	1.1	7.9	Standard
2711	7.40 7.64 7.64	7.56	1.4	7.6	British
7722	7.10 7.80 7.80	7.57	4.1	7.5	Standard
4311	7.60 7.60 7.60	7.60	0	7.1	SEC
4321	7.65 7.65	7.65	0	6.5	British
6552	7.40 7.90 7.65	7.65	2.2	6.5	Standard

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
6514B	7.65 7.70 7.70	7.68	0.3	6.1	Standard
1311	7.80 7.70 7.60	7.70	0.9	5.9	British
1311	7.75 7.75 7.60	7.70	0.8	5.9	SEC
4321	8.00 7.60 7.50	7.70	2.6	5.9	SEC
6914	7.80 7.70 7.60	7.70	0.9	5.9	Standard
6424	8.04 7.46 7.64	7.71	2.8	5.7	SEC
6514A	7.72 7.68 7.72	7.71	0.2	5.8	SEC
5811	8.04 7.68 7.45	7.72	2.7	5.6	British
6514B	7.75 7.70 7.70	7.72	0.3	5.6	SEC
6811	7.75 7.90 7.52	7.72	1.8	5.6	SEC

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
3731	7.80 8.40 7.00	7.73	6.3	7.2	SEC
5611	7.50 8.40 7.30	7.73	5.7	7.2	SEC
2411	7.66 7.80 7.80	7.75	0.8	5.2	SEC
2611	7.74 8.13 7.44	7.77	3.1	5.0	Standard
4511	8.05 7.55 7.70	7.77	2.4	5.0	SEC
5511	8.00 8.40 6.90	7.77	7.4	6.8	British
6424	8.00 7.67 7.72	7.80	1.7	4.7	British
1314	7.93 7.65 7.85	7.81	1.4	4.5	Standard
3811	7.56 7.99 7.92	7.82	2.2	4.4	British
6514A	7.76 7.88 7.88	7.84	0.7	4.2	British

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
7522	8.15 7.80 7.70	7.88	2.2	3.6	SEC
3611	7.83 8.13 7.88	7.95	1.5	2.8	British
2626	7.80 7.90 8.20	7.97	2.0	2.8	British
9113	8.00 8.00 7.90	7.97	0.5	2.6	British
1211	8.00 8.06 7.96	8.01	0.4	2.1	British
2611	8.18 7.99 7.89	8.02	1.3	2.0	British
2711	8.13 8.01 8.01	8.05	0.6	1.6	Standard
1211	7.80 8.27 8.11	8.06	2.1	2.2	Standard
7222	7.89 8.14 8.18	8.07	1.5	1.3	SEC
8112	8.10 8.00 8.10	8.07	0.5	1.4	British

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
8512	8.00 8.20	8.10	1.2	1.2	SEC
4921	8.23 8.09 8.09	8.14	0.8	0.9	British
5111	8.00 8.40 8.10	8.16	1.9	2.0	Standard
1924	8.04 8.28 8.18	8.17	1.0	1.0	British
1911	8.10 8.20 8.30	8.20	0.8	0.9	Standard
3811	8.50 8.28 7.99	8.26	2.1	2.5	Standard
3711	8.33 8.13 8.50	8.32	1.5	2.1	Standard
3226	8.20 7.60 7.40 9.00 9.50	8.34	8.7	8.6	British
2311	8.50 8.25 8.30	8.35	1.2	2.1	Standard

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
5614	8.00 8.50 8.70	8.40	3.2	4.2	Standard
unidenti-fied	8.80 8.00 8.40	8.40	3.2	4.2	British
5614	8.40 8.50 8.50	8.47	0.5	3.5	SEC
unidenti-fied	8.80 8.20 8.50	8.50	2.3	3.9	Standard
9613	8.30 8.30 9.05	8.55	3.9	4.5	British
4421	8.50 8.65 8.65	8.60	0.8	5.1	Standard
5311	8.80 8.50 8.50	8.60	1.5	5.1	British
6411	8.55 8.80 8.55	8.63	1.3	5.5	SEC
8423	8.57 8.57 8.75	8.63	0.9	5.5	British
8613	8.40 8.88 8.80	8.69	2.2	6.3	SEC

Lab. No.	Results	Mean	Average % dev. within lab.	Average % dev. from established concentration	Method
7912	8.60 8.75 8.75	8.70	0.8	6.4	Standard
7722	8.70 8.80 8.70	8.73	0.5	6.8	British
4626	9.30 8.40 8.70	8.80	3.8	7.6	British
01	8.75 8.85 9.10	8.90	1.5	8.8	Standard
8512	9.00	9.00	-	10.0	British
5931	9.30 8.60 9.30	9.07	3.4	10.8	Standard

Table 4. SURFACTANT - Sample C - Surface Water
2.60 mg/l ABS Added

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
5111	0.09 0.08 0.09	0.09	2.10 1.90 2.14	2.05	4.7	1.96	24.6	SEC
8812A	0.16 0.15 0.16	0.16	2.13 2.13 2.12	2.13	0.2	1.97	24.2	SEC
1711A	0.00 0.00 0.00	0.00	2.24 2.16 2.05	2.15	3.1	2.15	17.3	British
3816	0.02	0.02	2.20	2.20	-	2.18	16.2	SEC
6711	0.36 0.15 0.36	0.29	2.38 2.35 2.78	2.50	7.3	2.21	15.0	British
1211	0.27 0.29 0.28	0.28	2.51 2.53 2.48	2.51	0.7	2.23	14.2	British
6424	0.09 0.09 0.10	0.09	2.53 2.11 2.36	2.33	6.4	2.24	13.8	British
4311	0.15 0.15 0.15	0.15	2.45 2.43 2.37	2.42	1.2	2.27	12.7	SEC

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
	0.04		2.37					
7112	0.06	0.05	2.27	2.32	1.6	2.27	12.7	SEC
	0.05		2.33					
	0.42		2.76					
6811	0.39	0.41	2.66	2.69	1.6	2.28	12.3	Standard
	0.42		2.66					
	0.21		2.60					
7222	0.16	0.17	2.44	2.46	3.6	2.29	11.9	Standard
	0.14		2.35					
	0.05		2.26					
3911	0.04	0.04	2.44	2.34	2.8	2.30	11.5	Standard
	0.04		2.32					
	0.20		2.56					
2716	0.16	0.16	2.48	2.47	2.8	2.31	11.2	SEC
	0.12		2.36					
	0.11		2.44					
4921	0.11	0.11	2.39	2.42	1.0	2.31	11.2	Standard
	0.10		2.44					
	0.04		2.34					
3711	0.04	0.04	2.61	2.36	7.0	2.32	10.8	Standard
	0.03		2.13					

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
7522	3.05 3.05 3.05	3.05	5.60 5.10 5.40	5.37	3.3	2.32	10.8	British
6424	0.15 0.15 0.14	0.15	2.52 2.48 2.44	2.48	1.1	2.33	10.4	SEC
1524	<0.01 <0.01 <0.01	<0.01	2.10 2.55 2.37	2.34	6.8	2.34	10.0	Standard
4421	0.00 0.00 0.00	0.00	2.34 2.39 2.30	2.34	1.3	2.34	10.0	SEC
5711	0.07 0.06 0.07	0.07	2.40 2.56 2.26	2.41	4.3	2.34	10.0	Standard
9613	0.00 0.00 0.00	0.00	2.30 2.56 2.16	2.34	6.3	2.34	10.0	SEC
5611	0.00 0.00 0.00	0.00	2.44 2.24 2.40	2.36	3.4	2.36	9.2	Standard

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
	0.00		2.25					
3211	0.00	0.00	2.55	2.37	5.2	2.37	8.8	SEC
	0.00		2.30					
	0.32		2.62					
2111	0.30	0.29	2.80	2.67	3.4	2.38	8.5	SEC
	0.26		2.58					
	0.00		2.24					
3911	0.00	0.00	2.40	2.38	3.9	2.38	8.5	SEC
	0.00		2.50					
	0.06		2.34					
3711	0.05	0.05	2.51	2.45	2.8	2.40	7.7	British
	0.05		2.49					
	3.64		6.16					
7522	3.70	3.73	6.28	6.13	1.9	2.40	7.7	SEC
	3.86		5.96					
	0.00		2.40					
6914	0.00	0.00	2.40	2.41	0.4	2.41	7.3	Standard
	0.00		2.42					
	0.20		2.66					
8222	0.17	0.17	2.56	2.58	1.9	2.41	7.3	Standard
	0.15		2.53					

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
1924	0.00 0.00 0.00	0.00	2.43 2.38 2.44	2.42	1.0	2.42	6.9	Standard
2411	0.11 0.10 0.10	0.10	2.56 2.48 2.52	2.52	1.0	2.42	6.9	Standard
4511	0.05 0.04 0.04	0.04	2.48 2.42 2.48	2.46	1.1	2.42	6.9	SEC
6512	0.00 0.00 0.00	0.00	2.43 2.45 2.37	2.42	1.2	2.42	6.9	British
unidentified	0.00 0.00 0.00	0.00	2.29 2.53 2.43	2.42	3.4	2.42	6.9	British
4511	0.02 0.02 0.02	0.02	2.40 2.54 2.42	2.45	2.3	2.43	6.5	Standard
6715	0.01 0.02 0.02	0.02	2.34 2.58 2.43	2.45	3.5	2.43	6.5	SEC

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
	0.30		2.72					
1211	0.27	0.28	2.73	2.72	0.4	2.44	6.2	Standard
	0.28		2.70					
	0.00		2.25					
3211	0.00	0.00	2.50	2.45	5.4	2.45	5.8	Standard
	0.00		2.60					
	0.15		2.60					
4311	0.16	0.15	2.62	2.60	0.4	2.45	5.8	Standard
	0.15		2.59					
	0.10		2.76					
2611	0.08	0.09	2.42	2.55	5.6	2.46	5.4	British
	0.10		2.46					
	0.01		2.50					
6914	0.01	0.01	2.40	2.47	1.8	2.46	5.4	SEC
	0.01		2.50					
	0.02		2.40					
7112	0.02	0.02	2.52	2.48	2.1	2.46	5.4	Standard
	0.02		2.52					
	0.04		2.40					
1711B	0.05	0.05	2.60	2.52	3.0	2.47	5.0	British
	0.05		2.55					

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
1924	0.00 0.00 0.00	0.00	2.47 2.47 2.47	2.47	0	2.47	5.0	British
3816	0.02	0.02	2.50	2.50	-	2.48	4.6	British
4611	0.15 0.15 0.18	0.16	2.66 2.62 2.64	2.64	0.5	2.48	4.6	SEC
5611	0.00 0.00 0.00	0.00	2.56 2.40 2.48	2.48	2.1	2.48	4.6	SEC
6715	0.00 0.00 0.00	0.00	2.35 2.45 2.65	2.48	4.4	2.48	4.6	British
1611	0.06 0.06 0.15	0.09	2.50 2.75 2.50	2.58	4.3	2.49	4.2	SEC
6512	0.03 0.03 0.03	0.03	2.59 2.53 2.45	2.52	2.0	2.49	4.2	SEC
1311	0.00 0.00 0.00	0.00	2.50 2.50 2.50	2.50	0	2.50	3.8	British

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
6212	0.03 0.05 0.02	0.03	2.70 2.40 2.50	2.53	4.3	2.50	3.8	Standard
1311	0.00 0.00 0.00	0.00	2.53 2.50 2.50	2.51	0.5	2.51	3.5	Standard
1311	0.00 0.00 0.00	0.00	2.48 2.52 2.52	2.51	0.6	2.51	3.5	SEC
4511	0.05 0.06 0.07	0.06	2.60 2.56 2.54	2.57	0.9	2.51	3.5	British
2411	0.12 0.11 0.11	0.11	2.60 2.68 2.60	2.63	1.4	2.52	3.1	SEC
6811	0.48 0.42 0.45	0.45	2.97 3.03 2.90	2.97	1.4	2.52	3.1	SEC
7912	0.04 0.04 0.03	0.04	2.45 2.45 2.77	2.56	5.6	2.52	3.1	SEC

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
	0.22		2.76					
8812A	0.20	0.21	2.70	2.73	0.8	2.52	3.1	Standard
	0.20		2.72					
	0.13		2.71					
7512	0.13	0.13	2.83	2.66	5.5	2.53	2.7	Standard
	0.13		2.44					
	0.00		2.25					
01	0.00	0.00	2.75	2.54	7.6	2.54	2.3	Standard
	0.00		2.62					
	0.14		2.90					
3731	0.09	0.09	2.50	2.63	6.7	2.54	2.3	Standard
	0.03		2.50					
	0.03		2.64					
6514A	0.03	0.03	2.52	2.57	1.7	2.54	2.3	SEC
	0.03		2.56					
	0.17		2.66					
8222	0.16	0.16	2.73	2.70	0.9	2.54	2.3	SEC
	0.16		2.70					
	0.11		2.66					
2611	0.10	0.10	2.71	2.65	1.6	2.55	1.9	Standard
	0.09		2.59					

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
3226	0.02 0.02 0.02	0.02	2.56 2.64 2.52	2.57	1.7	2.55	1.9	SEC
5711	0.16 0.18 0.15	0.16	2.75 2.78 2.61	2.71	2.6	2.55	1.9	SEC
6212	0.06 0.05 0.05	0.05	2.60 2.60 2.60	2.60	0	2.55	1.9	SEC
9223	4.12 4.16 4.20	4.16	6.76 6.64 6.72	6.71	0.6	2.55	1.9	Standard
1524	0.01 0.01 0.01	0.01	2.60 2.65 2.46	2.57	2.8	2.56	1.5	British
1611	0.10 0.12 0.15	0.12	2.75 2.90 2.40	2.68	7.1	2.56	1.5	Standard
1814	0.11 0.13 0.12	0.12	2.67 2.73 2.64	2.68	1.2	2.56	1.5	SEC

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
5511	0.01 0.01	0.01	2.54 2.60	2.57	1.2	2.56	1.5	British
5511	0.01 0.02	0.02	2.36 2.80	2.58	8.5	2.56	1.5	Standard
6411	0.02 0.02 0.02	0.02	2.58 2.59 2.58	2.58	0.1	2.56	1.5	Standard
1711B	0.12 0.13 0.14	0.13	2.60 2.75 2.75	2.70	2.5	2.57	1.2	SEC
1911	0.08 0.10 0.09	0.09	2.58 2.68 2.72	2.66	2.0	2.57	1.2	Standard
7222	0.20 0.28 0.22	0.23	2.81 2.88 2.71	2.80	2.1	2.57	1.2	SEC
8613	0.63 0.65 0.59	0.62	3.18 3.14 3.26	3.19	1.4	2.57	1.2	Standard
1711A	0.02 0.03 0.02	0.02	2.54 2.56 2.70	2.60	2.6	2.58	0.8	Standard

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
	0.03		2.66					
3611	0.03	0.03	2.57	2.61	1.4	2.58	0.8	Standard
	-		2.59					
	0.03		2.60					
5221	0.02	0.02	2.60	2.60	0	2.58	0.8	Standard
	0.02		2.60					
	0.00		2.58					
5311	0.00	0.00	2.66	2.58	2.1	2.58	0.8	SEC
	0.00		2.50					
	0.03		2.59					
8423	0.03	0.03	2.64	2.61	0.9	2.58	0.8	Standard
	0.03		2.59					
	0.08		2.75					
3111	0.08	0.08	2.50	2.67	4.1	2.59	0.4	SEC
	0.09		2.75					
	0.02		2.56					
3226	<0.02	0.02	2.60	2.61	1.6	2.59	0.4	British
	0.02		2.68					
	0.12		2.64					
5111	0.05	0.08	2.70	2.67	0.9	2.59	0.4	Standard
	0.08		2.68					

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
5221	0.03 0.03 0.02	0.03	2.65 2.60 2.60	2.62	0.9	2.59	0.4	SEC
2311	0.01 0.00 0.01	0.01	2.64 2.63 2.55	2.61	1.4	2.60	0	British
4611	0.14 0.17 0.15	0.15	2.74 2.72 2.80	2.75	1.1	2.60	0	British
8512	0.00 - -	0.00	2.60 - -	2.60	-	2.60	0	SEC
2626	0.09 0.08 0.09	0.09	2.90 2.50 2.70	2.70	4.9	2.61	0.4	SEC
3611	0.05 0.05 0.05	0.05	2.66 2.66 2.66	2.66	0	2.61	0.4	British
4421	0.10 0.00 0.00	0.00	2.58 2.58 2.66	2.61	1.4	2.61	0.4	Standard

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
	0.02		2.70					
7813	0.02	0.02	2.60	2.63	1.6	2.61	0.4	Standard
	0.02		2.60					
	0.11		2.76					
1911	0.13	0.11	2.70	2.73	0.8	2.62	0.8	SEC
	0.10		2.74					
	0.00		2.64					
4321	-	0.00	2.60	2.62	0.8	2.62	0.8	British
	-		-					
	9.10		12.00					
4626	9.00	9.13	11.75	11.75	1.4	2.62	0.8	SEC
	9.30		11.50					
	0.17		3.00					
9113	0.16	0.17	2.70	2.80	4.8	2.63	1.2	British
	0.17		2.70					
	0.04		2.66					
7512	0.04	0.04	2.69	2.68	0.5	2.64	1.5	British
	0.03		2.69					
	0.05		2.70					
7813	0.04	0.04	2.65	2.68	0.6	2.64	1.5	SEC
	0.03		2.68					

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
	0.02		2.60					
7912	0.01	0.01	2.70	2.65	1.2	2.64	1.5	Standard
	0.01		2.65					
	0.08		2.84					
1814	0.09	0.08	2.67	2.75	2.2	2.67	2.7	Standard
	0.08		2.74					
	0.00		2.86					
5311	0.00	0.00	2.68	2.68	4.5	2.68	3.1	British
	0.00		2.50					
unidenti-	0.00		2.75					
fied	0.00	0.00	2.60	2.68	1.9	2.68	3.1	Standard
	0.00		2.68					
	0.07		2.75					
3111	0.10	0.08	2.75	2.77	0.8	2.69	3.5	British
	0.08		2.80					
	0.03		2.53					
3811	0.04	0.03	2.79	2.72	4.8	2.69	3.5	British
	0.01		2.85					
	0.00		2.63					
5811	0.00	0.00	2.73	2.70	1.6	2.70	3.8	British
	0.00		2.73					

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
5821	0.08 0.06 0.08	0.07	2.80 2.80 2.70	2.77	1.6	2.70	3.8	SEC
8512	0.00 - -	0.00	2.70 - -	2.70	-	2.70	3.8	British
1113	0.08 0.08 0.12	0.09	2.80 2.80 2.86	2.82	0.9	2.73	5.0	Standard
3731	0.21 0.12 0.18	0.17	3.10 2.90 2.70	2.90	4.6	2.73	5.0	SEC
6514A	0.05 0.04 0.06	0.05	2.76 2.80 2.80	2.79	0.6	2.74	5.4	British
2526	0.00 0.00 0.00	0.00	2.75 2.80 2.70	2.75	1.2	2.75	5.8	British
2626	0.07 0.08 0.10	0.08	2.80 2.80 2.90	2.83	1.5	2.75	5.8	British

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
	0.00		2.80					
4321	0.00	0.00	2.70	2.75	1.8	2.75	5.8	SEC
	-		-					
	0.00		2.75					
8112	0.00	0.00	3.00	2.75	6.1	2.75	5.8	SEC
	0.00		2.50					
	0.26		2.96					
2711	0.26	0.27	3.06	3.03	1.4	2.76	6.2	British
	0.30		3.06					
	0.00		2.70					
5614	0.00	0.00	2.80	2.77	1.6	2.77	6.5	Standard
	0.00		2.80					
	4.34		7.16					
9223	4.60	4.49	7.32	7.27	1.0	2.78	6.9	British
	4.52		7.32					
	0.03		2.83					
3811	0.01	0.01	2.69	2.81	3.0	2.80	7.7	Standard
	0.00		2.92					
	1.08		3.85					
4523	1.09	1.08	3.83	3.88	1.3	2.80	7.7	Standard
	1.06		3.95					

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
	0.00		2.80					
5614	0.00	0.00	2.80	2.80	0	2.80	7.7	SEC
	0.00		2.80					
	0.00		2.80					
8112	0.00	0.00	2.80	2.80	0	2.80	7.7	British
	0.00		2.80					
	7.10		9.80					
4711	6.75	6.98	10.00	9.80	1.4	2.82	8.5	SEC
	7.10		9.60					
	0.00		2.72					
01	0.00	0.00	2.88	2.83	2.5	2.83	8.8	SEC
	0.00		2.88					
	6.00		9.30					
4626	5.80	6.10	9.00	8.93	3.2	2.83	8.8	British
	6.50		8.50					
	0.14		3.00					
9113	0.17	0.15	3.00	3.00	0	2.85	9.6	Standard
	0.15		3.00					
	1.27		4.13					
4523	1.27	1.27	4.13	4.13	0	2.86	10.0	SEC
	1.28		4.13					

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
2711	0.27 0.30 0.27	0.28	3.16 3.16 3.19	3.17	0.4	2.89	11.2	Standard
9613	0.00 0.00 0.00	0.00	2.78 2.78 3.12	2.89	5.2	2.89	11.2	Standard
2716	0.12 0.12 0.15	0.13	3.08 3.04 2.96	3.03	1.4	2.90	11.5	British
9613	0.00 0.00 0.00	0.00	2.82 2.96 2.92	2.90	1.8	2.90	11.5	British
2311	0.04 0.04 0.04	0.04	2.91 3.00 3.00	2.97	1.3	2.93	12.7	Standard
6411	0.07 0.07 0.09	0.08	3.02 3.10 2.94	3.02	1.8	2.94	13.1	SEC
5811	0.00 0.00 0.00	0.00	3.03 3.03 2.78	2.95	3.7	2.95	13.5	Standard

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
1511	0.20 0.12 0.11	0.14	3.24 3.00 3.10	3.11	2.7	2.97	14.2	British
8423	0.02 0.01 0.01	0.01	2.96 2.96 3.04	2.99	1.2	2.98	14.6	British
1511	0.15 0.10 0.15	0.13	3.28 3.08 3.08	3.15	2.8	3.02	16.2	Standard
6612	0.40 0.43 0.45	0.43	3.40 3.50 3.50	3.47	1.2	3.04	16.9	Standard
2526	0.00 0.00 0.00	0.00	3.00 3.15 3.00	3.05	2.2	3.05	17.3	SEC
6612	0.45 0.45 0.46	0.45	3.50 3.50 3.50	3.50	0	3.05	17.3	SEC
8613	0.68 0.72 0.74	0.71	3.94 3.92 3.86	3.91	0.8	3.20	23.1	SEC

Lab. No.	ABS in surface water	Mean ABS in surface water	Total after addition of ABS	Mean of total ABS	Average % dev. within labs. for total ABS	Amount of added ABS recovered	% dev. of amt. recovered from amt. added	Method
	0.05		3.30					
6514B	0.05	0.05	3.30	3.28	0.7	3.23	24.2	Standard
	0.04		3.25					
	7.00		10.00					
4711	7.00	7.04	10.50	10.33	2.2	3.29	26.5	Standard
	7.12		10.50					
	0.04		3.40					
6514B	0.05	0.04	3.40	3.38	0.7	3.34	28.5	SEC
	0.04		3.35					

BRITISH METHOD*

THE COLORIMETRIC DETERMINATION OF ANIONIC SURFACE-ACTIVE MATERIALS IN WATER

By D. C. ABBOTT

(Department of Scientific and Industrial Research,
Laboratory of the Government Chemist,
Dudley House, Endell Street, London, W. C. 2)

"An improved version of Longwell and Maniece's method for determining trace amounts of anion-active materials in sewage, sewage effluents, river waters, etc., is proposed. By pre-extraction of the reagents, the blank value is kept low, thereby rendering the method particularly applicable to river and drinking waters containing extremely small amounts of anion-active material. Also, the removal of impurities usually present in methylene blue leads to an increase in sensitivity of about 15 percent and should improve reproducibility of standards between laboratories. Results by the improved method are similar to those by Longwell and Maniece's method, but emulsification is usually less."

REAGENTS —

All materials should be of recognised analytical grade; solutions should be prepared in ion-free water.

Alkaline borate solution - Mix equal volumes of 0.05 M sodium tetraborate and 0.10 N sodium hydroxide.

Sulphuric acid, approximately 1.0 N.

*TO PARTICIPANTS USING THE BRITISH METHOD: Please substitute the enclosed powdered alkyl benzene sulfonate for the Manoxol O. T. solution specified in this method. Report results as mg/l ABS.

Methylene blue solution - Dissolve 0.25 g of the B.P. or "vital-stain" grade material in water, and dilute to 1 litre.

Chloroform - This must be free from ethanol and detergent. Wash the chloroform twice with dilute (1 + 100) methylene blue solution, distil over burnt lime, and filter the distillate through anhydrous sodium sulphate.

Manoxol O.T. solution - Dissolve 1.00 g of Manoxol O.T., sodium dioctylsulphosuccinate, in water, and dilute to 1 litre. Dilute 10 ml of this solution to 1 litre as required to give a solution containing 10 μg of Manoxol O.T. per ml.

PROCEDURE —

Measure into a glass-stoppered 250-ml separating funnel 50 ml of water, 10 ml of alkaline borate solution and 5 ml of methylene blue solution. Add 10 ml of chloroform, shake for 30 seconds, and allow to separate. Run off the chloroform layer as completely as possible and rinse the aqueous layer, without shaking with 2 to 3 ml of chloroform; repeat the extraction with a further 10 ml of chloroform, and rinse as before. Take care that none of the aqueous phase enters the tap of the funnel.

Into a second similar funnel measure 100 ml of water, 10 ml of alkaline borate solution and 5 ml of methylene blue solution. Extract twice with 10-ml portions of chloroform as described above. To the extracted aqueous layer in this funnel immediately add 3 ml of 1 N sulphuric acid, mix well, and ensure that the tap and stem of the funnel are dry.

In the first separating funnel place a suitable volume of the sample, preferably not exceeding 100 ml and containing 50 to 100 μg of anion-active material. (Generally, take up to 10 ml of settled sewage, 50 ml of sewage effluent, and 100 ml of river or drinking water.) Add 15 ml of chloroform to the contents of this funnel, and shake evenly and gently twice a second for 1 minute, preferably in the horizontal plane. Allow the layers to separate as completely as possible, and swirl the funnel to dislodge droplets from its walls. (It is frequently advantageous to incline the funnel and then rotate it slowly about an almost horizontal axis to break up the fine emulsion coating its walls.) Allow to settle for 2 minutes, and then run as much as possible of the chloroform layer into

the second separating funnel containing the extracted and acidified methylene blue solution.

Shake the contents of this funnel as described in the previous paragraph, allow the layers to separate, dislodge the droplets and emulsion, and allow to settle for 2 minutes. Run the chloroform layer through a small filter-funnel plugged with cotton-wool (freshly washed with chloroform) into a clean dry 50-ml calibrated flask; allow none of the aqueous phase to enter the tap of the separating funnel.

Twice repeat the operations described above, beginning at "Add 15 ml of chloroform to the contents of this funnel...," combine the extracts in the flask, and dilute to the mark with chloroform.

Carry out a blank determination in an identical manner, and measure the optical densities at 650 mμ of the chloroform solutions from sample and blank; use 1-cm cells and chloroform as reference solution. Shake the flasks immediately before the cells are filled, and rinse each cell three times with the solution before reading the optical density.

Cells should be washed with chloroform after each reading. Frequently check the cell error by measuring the optical-density difference when chloroform is used in both cells, and correct for this error. If the cell error increases, clean the cells by immersing them in dilute nitric acid, rinsing with ion-free water and drying by means of acetone and chloroform. One cell should be marked and reserved for the reference chloroform. If the optical density of the solution from the sample when measured in 1-cm cells is less than about 0.1, repeat the measurement on the same solutions in 4-cm cells, taking all the precautions listed above.

Ascertain the number of micrograms of anion-active material equivalent to the difference between the observed optical densities of the blank and sample solutions from a previously prepared calibration graph corresponding to the size of cell used, and so obtain the net measure of the anion-active matter present in the sample; express this result in terms of milligrams of Manoxol O.T. per litre.

Establish calibration points by treating as described above suitable amounts of diluted Manoxol O.T. solution covering the range 0 to 200 μg of anion-active material. (Measure the corresponding optical densities in both 1- and 4-cm cells for amounts of Manoxol O.T. less than 40 μg and in 1-cm cells above this value.) Construct graphs relating optical density directly into micrograms of Manoxol O.T. by using a factor given by the slope of the calibration graph.

DETERMINATION OF SURFACTANT BY THE SEC MODIFIED METHYLENE BLUE PROCEDURE

All glassware, especially the separating funnels should be scrupulously cleaned before use. A recommended procedure for washing is:

1. Preliminary wash with warm, 5% tri-sodium phosphate.
2. Rinse with tap water, three times.
3. Rinse with warm acid dichromate cleaning solution.
4. Rinse with tap water and distilled water, each three times.

REAGENTS:

Methylene blue solution: dissolve 0.35 gms methylene blue in one liter of .01 N sulfuric acid.

Chloroform, C. P.

Sulfuric Acid, 5 N

Stock Standard ABS, 1.00 mg/ml

Working Standard ABS, 0.010 mg/ml

GLASSWARE:

Separatory funnels, 250 or 125 ml

Volumetric flasks, 50 ml

Filtering funnels

Pipettes, assorted sizes

PREPARATION OF STANDARD (Alkyl Benzene Sulfonate) SOLUTIONS:

Stock Standard: Weigh out 1.0142 grams of the 49.3% Primary Standard ABS powder, transfer quantitatively to a 500 ml volumetric flask and add 250 ml of distilled water. Swirl gently until all of the

powder is dissolved, let stand for one-half hour or until most of foam breaks and then make up to mark with distilled water. This solution contains 1.00 mg/ml of ABS.

Working Standard: Pipette 10.0 ml of the stock standard into a 1.0 liter volumetric flask and make up to mark. This solution contains 0.010 mg/ml of ABS. Prepare fresh daily.

PROCEDURE:

1. Add 0, 1.0, 2.0, 5.0, 10.0, 20.0, and 25.0 ml of Working Standard ABS to separatory funnels and make up to 100 ml with distilled water. These standards contain 0, .01, .02, .05, .10, .20, and .25 mg of ABS.

2. Add 100 ml or an aliquot of sample to a separatory funnel.

3. Add 1.0 ml of 5 N sulfuric acid and 5.0 ml of methylene blue solution to each separatory funnel and mix.

4. Add 10 ml of chloroform to each funnel, invert and shake once a second for 25 seconds. Allow the chloroform layer to separate.

5. Draw off the chloroform layer and filter through a plug of absorbent cotton into a 50-ml volumetric flask. Repeat the extraction twice more, using 10-ml portions of chloroform, collecting the extracts in the same flask.

6. Rinse the cotton plugs with chloroform into the 50-ml volumetric flask, make up to mark with chloroform, mix well and let stand for 5 - 10 minutes.

7. Read the optical density of the Reagent Blank and Standards against chloroform as a reference blank at 650 mμ in a suitable photometer or spectrophotometer and prepare a standard curve.

8. Read the optical density of each sample in a similar manner and calculate mg/l of ABS in each portion. Report all results to the second decimal place.

STANDARD METHOD

METHYLENE BLUE METHOD (Tentative)

Standard Methods for the Examination of Water and Wastewater, 11th Edition, 1960. American Public Health Association, American Water Works Association, Water Pollution Control Federation.

1. GENERAL DISCUSSION

1.1 Principle: This method depends on the formation of a blue-colored salt when methylene blue reacts with anionic surfactants, which include, not only ABS, but alkyl sulfates as well. The salt is soluble in chloroform, and the intensity of color is proportional to the concentration. The intensity is measured by making spectrophotometric readings in this solvent at a wavelength of 652 mμ. The method is applicable in the 0.025 - 100 mg/l (as ABS) range.

1.2 Interference: Both organic and inorganic compounds interfere with the determination of ABS. Some of the proved interferences can be predicted on the basis of chemical properties. Organic sulfates, sulfonates, carboxylates, phosphates, and phenols - which complex methylene blue - and inorganic cyanates, chlorides, nitrates, and thiocyanates - which form ion pairs with methylene blue - are among the positive interferences. Organic materials, especially amines, which compete with the methylene blue in the reaction, can cause low results. Positive errors are much more common than negative when determining anionic surfactants in water.

1.3 Minimum detectable concentration: 0.01 mg ABS.

2. APPARATUS

2.1 Spectrophotometer, for use at 652 mμ, providing a light path of 1 cm or longer.

2.2 Separatory funnels, 500 ml.

3. REAGENTS

3.1 Standard alkyl benzene sulfonate (ABS) solution: Weigh an amount of the reference material (obtain from Association of American Soap and

Glycerine Producers, New York) equal to 1.000 g ABS on a 100 percent active basis. Dissolve in distilled water and dilute to 1,000 ml. Dilute 10.00 ml of this stock solution to 1,000 ml with distilled water; 1.00 ml = 0.010 mg ABS.

3.2 Phenolphthalein indicator solution: Dissolve 5 g phenolphthalein in 500 ml 95 percent ethyl or isopropyl alcohol and add 500 ml distilled water. Then add 0.02 N NaOH dropwise until a faint pink color appears.

3.3 Sodium hydroxide, 1 N. Dissolve 40 g NaOH in distilled water and dilute to 1 liter.

3.4 Sulfuric acid, 1 N. Cautiously dilute 28 ml conc H_2SO_4 to 1 liter with distilled water.

3.5 Chloroform, ACS grade.

3.6 Methylene blue reagent: Dissolve 0.1 g methylene blue* in 100 ml distilled water. Transfer 30 ml of this solution to a 1-liter flask. Add 500 ml distilled water, 6.8 ml conc H_2SO_4, and 50 g monosodium dihydrogen phosphate monohydrate, $NaH_2PO_4 \cdot H_2O$ and shake until dissolution is complete. Dilute to the 1-liter mark.

3.7 Wash solution: Add 6.8 ml conc H_2SO_4 to 500 ml distilled water in a 1-liter flask. Then add 50 g $NaH_2PO_4 \cdot H_2O$ and shake until dissolution is complete dilute to the 1-liter mark.

4. PROCEDURE

4.1 Preparation of calibration curve: Prepare a series of ten separatory funnels with 0.00, 1.00, 3.00, 5.00, 7.00, 9.00, 11.00, 13.00, 15.00, and 20.00 ml of the standard ABS solution. Add sufficient water to make the total volume 100 ml in each separatory funnel. Treat each standard as described in Sec. 4.3 and plot a calibration curve of mg ABS versus absorbance.

4.2 Volume of sample: The volume of the water sample to be tested is based on the expected ABS concentration:

*Eastman No. P573 or equivalent.

Expected ABS Concentration - mg/l			Sample Taken ml
0.025	-	0.080	400
0.08	-	0.40	250
0.4	-	2.0	100
2	-	10	20.0
10		100	2.00

If a sample of less than 100 ml is indicated, dilute to 100 ml with distilled water; if 100 ml or more is used, extract the entire sample.

4.3 Extraction and color development:

a. Make the solution alkaline by adding NaOH, using phenolphthalein as the indicator. Then acidify with H_2SO_4 and transfer to a separatory funnel.

b. Add 10 ml chloroform and 25 ml methylene blue. Rock vigorously for 30 sec and allow the phases to separate. Excessive agitation may cause emulsion trouble. Some samples require a longer period of phase separation than others.

c. Draw off the chloroform layer into a second separatory funnel. Rinse the delivery tube of the first separatory funnel with a small amount of chloroform. Repeat the extraction three times, using 10 ml chloroform each time. If the blue color in the water phase becomes faint and disappears, add 25 ml more methylene blue.

d. Combine all extracts in the second separatory funnel. Add 50 ml wash solution and shake vigorously for 30 sec. Emulsions do not form at this stage. Allow to settle and draw off the chloroform layer through glass wool into a 100-ml volumetric flask. Repeat the washing twice more with 10 ml chloroform each time. Rinse the glass wool and the funnel with chloroform. Collect the washing in the volumetric flask, dilute to the mark, and mix well.

4.4 Measurement: Determine the absorbance of the solution at 652 mμ, against a blank of chloroform.

5. CALCULATION

$$\text{mg/l total apparent ABS} = \frac{\text{mg ABS} \times 1,000}{\text{ml sample}}$$

GLOSSARY OF STATISTICAL TERMS

A glossary of statistical terms with definitions of their meaning as used in these reports is presented to insure uniform and complete understanding.

Arithmetic Mean — The sum of a series of test results divided by the number in the series.

Median — The value above and below which an equal number of observations lie.

ACCURACY — Accuracy is the correctness of a measurement, or the degree of correspondence between the result and the true value.

ACCURACY DATA — Measurements which relate to the difference between the average test results and the true result when the latter is known or assumed. The following measures apply:

50% Range — The maximum deviation from the true amount for the more accurate half of the mean results reported.

Average deviation from true concentration — The average difference without regard to sign between each laboratory mean and the true value.

Average percent deviation from established concentration (or amount added) — The average of the differences between a laboratory's replicate results and the established concentration expressed as percentages of the established concentration.

PRECISION Precision is a measure of the reproducibility of measurements, or the degree to which the measurements correspond to one another.

PRECISION DATA Measurements which relate to the variation among the test results themselves, i.e., the scatter or dispersion of a series of test results without assumption of any prior information. The following measures apply:

Variance The sum of squares of deviations of the average test results from the mean of the series divided by one less than the total number of average test results.

Standard deviation The square root of the variance.

Coefficient of variation The standard deviation of the laboratories' means as a percentage of the mean of this series.

Range The difference in magnitude between the highest and lowest laboratory mean.

Average percent deviation within laboratory The average of the differences between a laboratory's replicate results and their mean, expressed as percentages of their mean.

Confidence limits Limits within which the true mean of the series will lie with a given probability.

REFERENCES

1. Annual Reviews. Analytical Chemistry. pg. 364R. April 1962.

2. Bennett, C.A., and Franklin, N.L. Statistical Analysis in Chemistry and The Chemical Industry. John Wiley & Sons, Inc. New York. 1954.

3. Bauer, E.L. A Statistical Manual for Chemists. Academic Press. New York. 1960.

4. Dixon, W.J., and Massey, F.J. Introduction to Statistical Analysis. McGraw-Hill Book Co., Inc. New York. 1951.

ANALYTICAL REFERENCE SERVICE MEMBERSHIP

STATE AGENCIES

Alabama Water Improvement Commission
Arizona State Department of Health
Arkansas State Board of Health
California State Department of Public Health (Berkeley)
California State Department of Public Health (Los Angeles)
California Department of Water Resources
California Disaster Office
Colorado State Department of Public Health
Connecticut State Department of Health
Delaware Water Pollution Commission
Florida State Board of Health (Bureau of Laboratories, Jacksonville)
Florida State Board of Health (Division of Sanitary Engineering, Jacksonville)
Florida State Board of Health (Pensacola)
Florida State Board of Health (Winter Haven)
State of Hawaii Department of Health
Idaho Department of Health
Illinois State Department of Public Health (Chicago)
Illinois State Department of Public Health (Springfield)
Illinois State Water Survey Division
Indiana State Board of Health
Kansas State Board of Health (Sanitary Engineering Laboratories)
Kentucky State Department of Health
Louisiana State Board of Health
Maryland State Department of Health
Maryland State Water Pollution Control Commission
Massachusetts Department of Public Health
Massachusetts General Hospital
Michigan State Department of Health
Michigan Water Resources Commission
Minnesota State Department of Health
Missouri Department of Public Health and Welfare
Montana State Board of Health
Nebraska State Department of Health
Nevada State Department of Health (Las Vegas)
Nevada State Department of Health (Reno)
New Hampshire State Department of Health
New Hampshire Water Pollution Commission

New Jersey State Department of Health
New Mexico State Department of Public Health
New York State Department of Health
New York State Conservation Department
North Carolina Department of Water Resources
North Dakota State Department of Health
Ohio State Department of Health
Oklahoma State Department of Health
Oregon State Board of Health
Pennsylvania Department of Health
Puerto Rico Institute of Health Laboratories
Rhode Island Department of Health
South Carolina Water Pollution Control Authority
South Dakota Department of Health
Tennessee Division of Preventable Diseases
Tennessee Stream Pollution Control Board
Texas State Department of Health
Utah State Department of Health
Vermont State Department of Health
Vermont State Department of Water Resources
Virginia State Department of Health
Virginia State Water Control Board
Washington State Department of Health
West Virginia State Water Resources Commission
Wisconsin State Board of Health

MUNICIPAL AGENCIES

Air Pollution Control District, Pasadena
Baltimore City Health Department
Chicago Department of Air Pollution Control
Chicago Department of Water and Sewers, South District Filtration Plant
City of Charlotte, North Carolina, Water Department
City of Dayton, Department of Water
City of Durham, Department of Water Resources
City of Miami, Alexander Orr Jr., Water Treatment Plant
City of New York, Department of Health
City of Pasadena, Department of Public Health
Dayton Department of Service and Buildings
Erie County Laboratory (Buffalo)
Flint Water Plant, Department of Public Works and Utilities
Long Beach Water Department

Los Angeles County Flood Control District
Los Angeles Department of Public Works (Hyperion Treatment Plant)
Los Angeles Department of Water and Power
Louisville Water Company, Incorporated
Metropolitan Water District of Southern California
Omaha Metropolitan Utilities District
Philadelphia Department of Public Health
Philadelphia Department of Public Health (Occupational Environment Section)
Philadelphia Suburban Water Company
Philadelphia Water Department (Belmont Laboratory)
Philadelphia Water Department (Torresdale Laboratory)
St. Louis County Water Company
St. Louis Department of Health and Hospitals
Topeka, Kansas, Water Works

FEDERAL AGENCIES

Associated Universities, Incorporated, Brookhaven National Laboratory
DHEW, PHS, Great Lakes - Illinois River Basin Project
DHEW, PHS, Northeastern Radiological Health Laboratory, Winchester, Massachusetts
DHEW, PHS, Off-Site Radiological Safety Program, Las Vegas, Nevada
DHEW, PHS, Water Quality Section, Division of Water Supply and Pollution Control, Cincinnati, Ohio
Food and Drug Administration, Division of Pharmacology, Washington, D. C.
Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee
Pearl Harbor Naval Shipyard
Sixth U.S. Army Medical Laboratory, Fort Baker, California
Tennessee Valley Authority, Chattanooga, Tennessee (Stream Pollution Control)
Tennessee Valley Authority, Wilson Dam, Alabama (Occupational Health Branch)
2793D U.S. Air Force Hospital, Regional Environmental Health Laboratory, McClelland Air Force Base, California
2794th U.S. Air Force Dispensary - Class B, Kelly AFB, Texas
U.S. Air Force Radiological Health Laboratory, Wright-Patterson AFB, Ohio
U.S. Army Environmental Hygiene Agency, Maryland
U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado
U.S. Department of the Interior, Geological Survey, Columbus, Ohio
U.S. Department of the Interior, Geological Survey, Denver, Colorado
U.S. Department of the Interior, Geological Survey, Philadelphia, Pennsylvania
U.S. Department of the Interior, Geological Survey, Sacramento, California

UNIVERSITIES

Case Institute of Technology, Department of Civil and Sanitary Engineering
Columbia University
University of Florida, Department of Chemistry
Georgia Institute of Technology, Department of Applied Biology
Johns Hopkins University, School of Hygiene and Public Health
University of Kansas, School of Engineering and Architecture
New Mexico State University, Department of Civil Engineering
University of North Carolina, Chapel Hill, North Carolina
University of Pittsburgh, Graduate School of Public Health
Purdue University, Department of Chemistry
Rensselaer Polytechnic Institute, Troy, New York
Rutgers - The State University, Department of Sanitation
Washington State University, Division of Industrial Research

INDUSTRY

American Cyanamid Company, Bound Brook, New Jersey
Anaconda Company, Grants, New Mexico
Atlantic Refining Company, Philadelphia, Pennsylvania
Battelle Memorial Institute, Columbus, Ohio
Bethlehem Steel Company, Bethlehem, Pennsylvania
California Water Service Company, San Jose, California
Central Farmers Fertilizer Company, Montpelier, Idaho
Culligan, Incorporated, Northbrook, Illinois
Dearborn Chemical Company, Chicago, Illinois
Dow Chemical Company, Midland, Michigan
E.I. du Pont de Nemours and Co., Aiken, South Carolina
Ekroth Laboratories, Inc., Brooklyn, New York
Fairbanks, Morse, and Company, Research Center, Beloit, Wisconsin
Food Machinery and Chemical Corporation, Pocatello, Idaho
General Electric Company, Louisville, Kentucky
Goodyear Atomic Corporation, Piketon, Ohio
HALL Laboratories Division, Calgon Corporation, Pittsburgh, Pennsylvania
Hazleton Nuclear Science Corporation, Palo Alto, California
Industrial Chemicals, Inc., South Bend, Indiana
Ionics, Incorporated, Cambridge, Massachusetts
Kennecott Copper Corporation, Salt Lake City, Utah
Minute Maid Company, Anaheim, California
Monsanto Chemical Company, St. Louis, Missouri

NALCO Chemical Company, Chicago, Illinois
Pacific Gas and Electric Company, Emeryville, California
Pan American World Airways, Patrick Air Force Base, Florida
Pomeroy and Associates, Pasadena, California
Radiation Detection Company, Mountain View, California
Reynolds Electrical and Engineering Company, Las Vegas, Nevada
Roy F. Weston, Inc., Newtown Square, Pennsylvania
Sandia Corporation, Sandia Base, Albuquerque, New Mexico
Tracerlab, Inc., Richmond, California
Water Service Laboratories, Inc., New York, New York

FOREIGN

Beograd, Yugoslavia, University of Beograd
Bogota, Colombia, South America, National University of Colombia
Caracas, Venezuela, Instituto Nacional de Obras Sanitarias
Chesterfield, Derbyshire, England, The British Coke Research Association
Didcot, Berks, England, United Kingdom Atomic Energy Authority
Hamilton, Ontario, Canada, Department of Municipal Laboratories
Kingston, Jamaica, West Indies, Scientific Research Council
Leatherhead, Surrey, England, Central Electricity Research Laboratories
Leeds, England, Houldsworth School of Applied Science, The University of Leeds
London, England, The Permutit Company, Ltd.
Marlow, Buckinghamshire, England, The Water Research Association
Ottawa, Ontario, Canada, Department of National Health and Welfare
Ottawa, Ontario, Canada, Occupational Health Division, Department of National Health and Welfare
Sao Paulo - Brasil, Comissao Inter-Municipal de Controle da Poluicao das Aguas E Do Ar
Sydney, Australia, Metropolitan Water, Sewerage, and Drainage Board
Taiwan Institute of Environmental Sanitation, PHA, Taiwan
Pingtung Air Pollution Laboratory
Pingtung Organic Waste Laboratory
Taichung Water Laboratory
Tainun Water Laboratory
Taipei Milk Laboratory
Taipei Radiological Health Laboratory
Taipei Water Laboratory
Taitung Water Laboratory
Vancouver, B. C., Canada, Department of Health Services and Hospital Insurance
Vancouver, B. C., Canada, Department of National Health and Welfare

ANALYTICAL REFERENCE SERVICE

STAFF

F. S. Kelso, Chief
R. J. Lishka, Chemist
J. A. Bell, Statistician
R. A. Salter, Chemist
P. L. Kruse, Chemist
J. M. Matthews, Chemist
E. R. Spaulding, Secretary

ACKNOWLEDGEMENTS

The suggestions and technical review of the final report by the following persons are gratefully acknowledged:

D. G. BALLINGER, Supervisory Chemist
Technical Advisory and Investigations
Water Supply and Pollution Control

J. M. COHEN, Chemist, In Charge
Engineering Research

R. C. KRONER, In Charge
General Laboratory Services
National Water Quality Network